LOS ANGELES RIVER BRIDGES
Los Angeles
Los Angeles County
California

HAER No. CA-271

HAER
CA-271

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

REDUCED COPIES OF MEASURED DRAWINGS

HISTORIC AMERICAN ENGINEERING RECORD
National Park Service
U.S. Department of the Interior
1849 C St. NW
Washington, DC 20240

THE HISTORIC AMERICAN ENGINEERING RECORD

LOS ANGELES RIVER BRIDGES

HAER No. CA-271

Location: The fifteen bridges in this recording project are all within the City of Los Angeles. Twelve of the bridges cross the Los Angeles River, from Glendale/Hyperion Bridge at the north to Washington Boulevard Bridge at the south. The Franklin Avenue Bridge and Fourth Street over Lorena Avenue Bridge cross ravines, while the Sunset over Silverlake Bridge provides an important grade separation.

USGS Los Angeles Quadrangle, 7.5'
See individual bridge histories for UTM coordinates

Dates of Construction: 1909-1934
Dates of Retrofit: 1990-2002 (projected)
Retrofit Designers: Los Angeles Bureau of Engineering
Builders: See individual bridge histories
Present Owner: City of Los Angeles
Present Use: Bridges within the City of Los Angeles.
Significance: Built between 1909 and 1934, the river bridges group contains many of the finest examples of City Beautiful bridges and viaducts in the United States. This system of bridges and viaducts has played a crucial role in the development of the Los Angeles metropolitan area. Key elements in the establishment of traffic and settlement patterns, the structures allowed people to move themselves and goods across land and water barriers and promoted the successful establishment of commercial and residential areas. Through the use of the reinforced concrete arch, bridge builders harmonized architectural beauty and structural integrity, creating structures that unified the city and created pride in its public works.

On June 5, 1990, following the October 17, 1989 Loma Prieta earthquake in Northern California, the voters of the City of Los Angeles passed Proposition G, a $376 million seismic bond issue that included $78 million for the retrofit of the Los Angeles River bridges. Over the last decade the Bureau of Engineering of the City of Los Angeles Department of Public Works has been seismically retrofitting these bridges. All of the bridges have been rehabilitated in keeping with their historical architectural character. The retrofit and restoration of the fifteen bridges is as much an outstanding engineering achievement as their original design.

Historians: Portia Lee, Andrew Johnston, Elizabeth Watson, August 2000.

Project Information: The summer field team was under the direction of Eric N. DeLony, (Chief of HAER). The recording team included Andrew Johnston, field supervisor (University of California, Berkeley), and Erin Ammer (Tulane University), Jason Currie (U.S./ICOMOS, Ottawa, Canada), Grant Day (University of Illinois, Champaign-Urbana), David Greenwood (University of Southern California), and Heather Larson (University of California, Berkeley), architects; Portia Lee, project historian (California Archives, Los Angeles) and Elizabeth Watson, (City University of New York, The Graduate Center), historian; and Brian Grogan, photographer (El Portal, California). An additional drawing was done by German B. Calas (Bureau of Engineering). Project assistance was provided by Clark Robins, Alex Vidaurrazaga, Peter See, John Koo, Jim Wu, Raffi Massabki, Shashi Bhakta, Ejike Mbaruguru, and Wenn Chyn (City of Los Angeles, Bureau of Engineering); Amid Habbal (Vanir Construction Management); and Todd Croteau and Richard O'Connor (Historic American Engineering Record).

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PREFACE

This Historic American Engineering Record (HAER) 2000 recording project examines fifteen historic bridges within the City of Los Angeles. Twelve of these bridges cross the Los Angeles River. Two others span deep ravines and a third is an important grade separation. Built between 1909 and 1934, these bridges, as a group, are exceptional examples of City Beautiful bridges in the United States.

Over the last decade the Bureau of Engineering of the City of Los Angeles Department of Public Works has been seismically retrofitting these bridges. On June 5, 1990, following the Loma Prieta earthquake in Northern California, the voters of the City of Los Angeles, in a special election, passed Proposition G, a $376 million seismic bond issue that included $78 million for the retrofit of the Los Angeles River bridges. The Los Angeles River Bridges Recording Project was carried out during the summer of 2000 when the last of these bridge retrofits were underway.

The HAER team had at its disposal the documentary resources of the Bureau of Engineering. This included the original plans of the bridges from the early twentieth century as well as the "as-built" plans, both on microfilm in the "vault" at the Bureau of Engineering. Bridge log books, at the California Department of Transportation (CalTrans) in Sacramento, provided a history of the work that had been done to the bridges since they were built. Primary sources used by the team include minutes of City Council Meetings and Bureau of Engineering internal documents. The periodical *Southwest Builder and Contractor* featured many articles on the construction of the bridges. Local newspapers such as the *Los Angeles Times* were also instrumental for the history and the drawing set. A number of local libraries and state archives were consulted for the project. These include the Libraries of the University of Southern California and the University of California, Los Angeles. Files in the corporate archive of the Automobile Association of Southern California proved useful for research on early twentieth century development of road systems in the greater Los Angeles area.

Like many HAER projects documenting twentieth century works for which significant material exists, the task for the Los Angeles River bridges team became one of selection and condensation. Each of the fifteen bridges studied by the team has one page of carefully selected drawings that explain both the original design, and if retrofitted, the seismic design. Because a large quantity of documentation exists in archives, the drawing set focuses on the interpretation of these landmarks, and the researcher is referred to the measured drawings archived with the City of Los Angeles for additional information.

The reader is encouraged to read this narrative in conjunction with the accompanying sets of drawings and photographs, both contemporary and historic. Each of these three components of the recording project has been consciously shaped to provide complimentary information. The set of photographs includes both contemporary views of the bridges in the year 2000, and a carefully chosen selection of historic images. In the drawing set, the architects have attempted to illustrate views of the bridges, often in cutaway axonometric drawings, that are not visible any other way. Where the following narrative summarizes material that is better or more comprehensively handled elsewhere, footnotes direct the reader to the relevant sources.

There are sixteen HAER numbers included within the Los Angeles River Bridges Recording Project, one for each of the fifteen bridges studied and one number for the project as a whole. The researcher who is studying an individual bridge using the materials from the recording project is encouraged to view also the project material included under the general project number, CA-271. The material on individual bridges is highly focused on that bridge, whereas the general information will put that bridge within a broader historical context.

The authors wish to thank the following for their assistance with the project: the librarians of The Huntington Library; Ken Breisch at the University of Southern California; Matt Roth at the Automobile Club of Southern California; Lewis McAdams and Joe Linton of the Friends of the Los Angeles River, Victoria Yust and Ian McIlvaine of Tierra Sol y Mar, Inc. Thanks also to Dace Taube of the Regional Library Center, University of Southern California; and Jim Walker, Metropolitan Transit Authority Library. Special thanks go to John Koo, Jim Hao-Jen Wu, Raffi Massabki, Shashi Bhakta, Ejike Mbaruguru, and Wenn Chyn of the Bureau of Engineering, Department of Public Works, City of Los Angeles for their patient assistance. Special thanks also to: Amid Habbal of Vanir Construction Management who assisted the team in many ways throughout the project; German B. Calas of the Bureau of Engineering who assisted with the drawings of the Sunset Boulevard Bridge; and Diane Kane of District VII of the California Department of Transportation for being a friend of HAER. Most significantly thanks go to Clark W. Robins of the Bureau of Engineering, without whose efforts this project would never have been possible

INTRODUCTION

The narrative history is divided into a six chapter overview of the subject bridges under HAER number CA-271, and fifteen individual bridge histories each with their own HAER number. Chapter I, "Cultural and Natural Geography," sets the bridges in the context of Los Angeles in the early years of the twentieth century, and covers topics such as the Los Angeles River System and the problem of winter floods. It includes a case study of the first great river bridge, North Broadway (Buena Vista Bridge). Chapter II, "Transportation Infrastructure," discusses railroads, the interurban rail system and the political in-fight over a single union railroad station for the city. Chapter III, "Planning for the Bridges," relates the public and private efforts to set up a program to construct high-water, reinforced concrete arch bridges over the Los Angeles. This chapter emphasizes the role of organizations such as the Automobile Club of Southern California and the members of the city's power elite; the influential Major Traffic Street Plan of 1924; and the governmental and public push to finance the work through bridge bond issues. Chapter IV, "The Bridge Design and Approval Process," focuses on the seminal builders and designers of the Bureau of Engineering and the Municipal Arts Commission, whose oversight was instrumental in the aesthetics, design and monumentality of the river bridges. Chapters V and VI move from an explanation of the history of the seismic retrofit of the bridges during the 1990s to the retrofit technology itself, detailing the step-by-step process of designing and performing one of the retrofits.

Each of the individual bridge histories includes a description of the architectural and engineering features of the bridge, and explores their design and construction. The narrative, beginning with the social, economic and geographic conditions in the city in 1901, seeks to develop an understanding of why the bridges were built and who built them; to explain their architectural styles and engineering construction; and to bring their history up-to-date with the seismic retrofits of the 1990s.

CHAPTER I. CULTURAL AND NATURAL GEOGRAPHY

Los Angeles on the Eve of the Twentieth Century

In 1901 the City of Los Angeles had approximately 100,000 people, not a great sum by the standards of an eastern metropolis. Most Americans regarded Californians north and south as existing precariously on the rim of the continent, basking in sunshine, but hapless before an unpredictable natural environment that inundated them with floods or shook down their homes in earthquakes. In addition, as Los Angeles' beloved elder statesman and memoirist Harrison Newmark remarked with regret, the city suffered from an undesirable reputation with respect to its character: a pueblo at once violent and indolent, with very little promise for its future. Yet with the arrival of the transcontinental railroad, the Anglo population doubled, then trebled in a few short years. Many of these newcomers soon became concerned with civic affairs in the burgeoning city, and they set to work building their own twentieth-century metropolis inside the Los Angeles Basin. Planning for the present and the future was immediately wanted, along with leaders, men and women at once idealistic and practical, altruistic and self-interested, with the determination to make their visions real.[1]

Planning for the city's water needs came first. Late in 1901 City Treasurer William Workman persuaded New York bankers to underwrite the sale of bonds that would permit the city to buy Los Angeles' privately owned waterworks. The waterworks' former superintendent William Mulholland came with the bargain. By 1913, the Superintendent had engineered the mighty Owens Valley Aqueduct to give Newmark's prospering city the water system for urban development. Residents who had competed with upstream users and neighboring cities to draw down the river a quarter-century before, now had the luxury of a surplus for Municipal Water District Engineer Mulholland to store in aquifers. Upper riparian growers took the river waters to irrigate a system of crops and orchards that they hoped to ship to the eastern United States on the railroad corridors that traveled in parallel lines along the banks of the Los Angeles River. Industrial development also continued its spread along the riverbanks and except for winter months, little water flowed in the riverbed near downtown.[2]

[1] Harrison Newmark, *Sixty Years in Southern California* (Los Angeles: Dawson's Book Shop, 1984), 650; Leonard Pitt and Dale Pitt, "Railroads," in *Los Angeles A to Z* (Los Angeles: University of California Press, 1997), 416-418.

[2] Blake Gumprecht, *The Los Angeles River: Its Life, Death, and Possible Rebirth* (Baltimore: Johns Hopkins Press, 1999), 120; Catherine Mulholland, *William Mulholland and the Rise of Los Angeles* (Berkeley: University of California Press, 2000); Boyle Workman, *The City That Grew* (Los Angeles: Southland Publishing Co., 1936).

The city's business leaders and landowners cried out for development, the key to the city's prosperity. For the city to become rich in opportunities and amenities, it needed people. The land was here; the water could now be securely provided in the dry months. Between December and March, it came of its own free will, too often in a deluge as the River overflowed its bank and flooded the ground along the river. Along the river, commercial and residential traffic on trestle bridges and causeways waited for trains to pass and flood waters to recede. Without control of the river and efficient crossings, road and rail connections outside the downtown would stagnate.

The Los Angeles River System

Los Angeles River historian Blake Gumprecht points out that by 1914 the Los Angeles River had ceased to be the kind of flowing waterway the word "river" generally denotes. Most of its water was siphoned away as it flowed toward its channel, so that it had become essentially a dry bed, an "occasional hazard" that had to be controlled when the San Gabriel mountains sent exceptionally heavy winter rains down their stream channels. Two principal factors made river crossing unpredictable: rail trackage and river bridges. Transcontinental railroad and streetcar commuter tracks ran everywhere along the banks; wood and iron trestle bridges crossed the waterway in sixteen places. This problem was complicated by the fact that the Los Angeles River, dry in summer and a dangerous moving wall of water in flood years, often changed its course during high water. The railroads seized upon this phenomenon as an excuse for their reluctance to erect permanent bridges designed to withstand swift water flows. Near downtown, the city was reasonably well protected by railroad levees. However, as an exponentially increasing population built on more and more undeveloped land, run-off could not be absorbed. The consequence was an ever-increasing flood danger.[3]

Floods posed a particular problem for wood trestle bridges along the Los Angeles River. After heavy rains, streams in the watershed of the San Gabriel mountains sent debris flows down hillside gullies into the Arroyo Seco channel, carrying rocks and mud accumulated in the downhill run. At the confluence of the Arroyo Seco and the river, the crest heightened and the speed of the water increased, capturing everything in its path. Massive trees, dwellings and their contents, animals, objects of every description were swept along the flooded banks and into the torrent. As the racing debris flow traveled past the city, it swamped the railroads' earthen causeways and tore down the wood trestle bridges, taking them along for the ride to the Long Beach Harbor. The river subsided with the storm, but east-west travel across it became impossible until the roads and bridges were rebuilt. Successive floods in 1914, 1917 and 1924 cost millions in damage repair to the industrial development along the riverbank. Continuous rainfall in February of 1927 culminated on the afternoon of February 15 in a flood crest estimated at 13,000 cubic feet per second. Public support for better bridges became stronger and business interests increased their demands for high all-weather crossings.[4]

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[3] Gumprecht, *Los Angeles River*, 157, 171 and passim.

[4] Annual Reports of the Bureau of Engineering, 1927-1928, Los Angeles City Archives, Los Angeles, Calif.

North Broadway Bridge - A Case Study

North Broadway Bridge, originally called the Buena Vista Viaduct, was the first of the permanent, reinforced concrete, arch spandrel City Beautiful Bridges across the Los Angeles River. When it opened in 1911, the event was widely covered in the City's newspapers. The *Los Angeles Times* printed a full-elevation photo as a banner across the top of the local news section. Coverage also included a portrait of the district Councilman, R. W. Dromgold. The story of Buena Vista Viaduct offers valuable insights into the factors that influenced the construction of the Los Angeles river bridges.

A single word in large type topped the headline:

Majestic

Great Viaduct About Ready. Cars Run Over the Buena Vista Structure.

Describing the street railway line over the bridge as one of its "chief purposes," the story stated that the bridge provided an important link between the downtown core and the newly developing cities of Glendale, Eagle Rock and Pasadena. On the day of its opening, Buena Vista Viaduct was still sandwiched between two earlier wood bridges, Downey Avenue and Pasadena Avenue. These would soon be torn down and traffic rerouted since the bridge engineers had reconfigured the road for traffic safety. While the old bridges represented utility and necessity, according to the writer, tearing them down would relieve the landscape of a "blot." The new bridge with its massive pylons, balustrade handrails, and view bays, was an ornament to the city and represented confidence in the decades to come.[5]

The *Times* story offered a complete history of the building of the North Broadway Bridge, beginning with the determination of the East Side Improvement Association to have a proper bridge for their community. R.W. Dromgold of the Association apparently got a promise of cooperation from the Southern Pacific. He was then elected to the City Council from the East Side District with the unshakable intent to get the bridge built. Becoming a member of both the Bridge and Finance Committees, Dromgold persuaded the Southern Pacific to grant a right-of-way across their tracks, to dedicate a twenty-foot wide strip of its land to the west approach, and to contribute about a third of the cost of the $175,000 structure. The railroad and their subsidiary street railway got improvements of their own also. They were allowed to buy a portion of hillside in Elysian Park for $10,000 in order to increase track facilities on the west side of the bridge.[6]

Buena Vista/North Broadway is a paradigm of the bridge building process in the City in 1910. Interested citizens got the ball rolling by securing cooperation with business or industry, proceeded to work within the political structure to secure the necessary approvals from the city, and then the Bureau of Engineering took over. Two differences are apparent between North Broadway and the later structures: the bridge did not arise as part of any formal planning effort, and the design was divided between engineers and

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[5] George W. Burton, "People's Need Makes Demand," *Los Angeles Sunday Times*, 11 Sept. 1911.

[6] "Great Viaduct About Ready." *Los Angeles Times*, 24 Sept. 1911, pt. II, 1, 6.

architects. Homer Hamlin, the City Engineer, was credited for the bridge's engineering, while the structure's magnificent classical ornamentation and architectural design was done by private architect Alfred F. Rosenheim. Rosenheim, the dean of Los Angeles Beaux-Arts architects, had been a member of the Municipal Arts Commission, an appointed City commission that reviewed the design of all municipal buildings. The building of Buena Vista Viaduct shows that citizens could speed the city's transportation development by action at the City Council – whose members were all-powerful over land-use decision in their districts – by enlisting city agencies such as the Bureau of Engineering, and by demanding the cooperation of the railroads and street railways that were always seeking profitable expansion of their lines.

CHAPTER II. TRANSPORTATION INFRASTRUCTURE

Railroads and the Interurban System

In 1911 the titans of the Southern California interurban and urban street railway systems, Edward H. Harriman and Henry Huntington, reached a historic agreement. Huntington had organized the Pacific Electric Street Railway in 1901; by 1903 he had the majority interest. The car line was not profitable in itself, but Huntington would soon realize giant profits from his ownership. Setting up the Huntington Land and Improvement Company, he extended the lines into undeveloped areas that he owned. By subdividing this acreage and selling lots, he amassed a fortune.[7]

Harriman, president of the Southern Pacific Railroad, observed Huntington's expanding empire, and decided to compete. Harriman acquired the Los Angeles Railway Company and a forty-five percent interest in the Pacific Electric – popularly known as the PE – from some of Huntington's disaffected stockholders. Huntington countered with a strategic proposition, and the two came to an understanding. In 1911, Harriman's Southern Pacific Company acquired the PE, monopolizing interurban transportation with 165 miles of single track and 290 miles of double track. Huntington's Los Angeles Railway Corporation dominated local transit with 350 miles of single track and 170 miles of double track. In the same year that the Buena Vista Viaduct, Old Seventh Street Bridge and Main Street Bridge went into operation, the street railways became the indispensable link between the downtown core and adjacent territory. Street railways influenced the development of Los Angeles as a horizontal city, but the downtown core remained the hub of a 1,425 square mile territory of agricultural and commercial enterprise linked to all parts of the city.[8] In the next decade, interurban rails would be extended to the east over the river bridges and continue far beyond the borders of the city of Los Angeles.

[7] Huntington's methods were widely admired and followed by later developers. See Carey McWilliams, *Southern California: An Island on the Land.* (1946; reprint, Salt Lake City: Peregrine Smith Books, 1973),133-134.

[8] Robert M. Fogelson, *The Fragmented Metropolis* (Berkeley: University of California Press, 1967,) 91-92; Spencer Crump, *Ride the Big Red Cars* (Costa Mesa, California, 1965), 175ff.

The Fight for Union Station

Permanent high-water crossings across the Los Angeles River had long been captive to the power of the national railroads that were zealous in asserting their rights-of-way along the riverbed. Boyle Workman, Los Angeles pioneer historian and long-time City Council President, recalled in his memoirs, "Los Angeles had to battle for every one of its major developments, and the project of a new Union Passenger Terminal and the removal of grade crossings were no exception to the rule."[9]

When the railroads arrived in Los Angeles in the 1870s and 1880s, they chose the flat lands on both sides of the river to lay track. The Southern Pacific built its Arcade Station, and Union Pacific built the La Grande Station, as their respective city termini. By 1910, the Santa Fe Railroad and the Los Angeles and Salt Lake Railways joined the group. All lines converged on downtown Los Angeles.[10] In 1911 civic groups petitioned the City Council for a solution. City Planner Bion J. Arnold went to Council and presented a plan to remove all north and south railroad passenger traffic to the banks of the river, placing rail lines under permanent high bridges. He also recommended concentration of traffic in a Union Terminal in the neighborhood of the Old Los Angeles Plaza.[11]

All the railroads united in opposition. When the California State Railroad Commission intervened, the railroads refused to accept its jurisdiction and went to litigation. In 1917 the Commission began public hearings. Meanwhile the Los Angeles City Council voted to provide $20,000 to help finance the necessary surveys of land for the proposed terminus.[12]

For the duration of World War I, the Federal Government operated the railroads, so the issue remained unresolved. In 1920, the Chief Engineer for the California State Railroad Commission upheld the Arnold plan. Once again the railroads balked, although the SP offered to erect a system of wooden trestles in order to eliminate grade crossings. Los Angeles City Council refused this old-fashioned and dangerous technology, and the fight went on. Finally, on 26 April 1921, the State Railroad Commission issued an order requiring the city and county, railroads and transit lines, to cooperate in the construction of grade separations between city streets and rail crossings.[13]

The struggle with the railroads impeded high bridge construction for the years between the completion of Buena Vista Viaduct in 1911 and Macy Street Bridge in 1924. However, with the State Railroad Commission's order, the city had a firm ally in its determination to eliminate the bottlenecks of railroad grade crossings over the river. In May 1921, the Los Angeles City Council, with Boyle Workman presiding, moved to

[9] Workman, *City That Grew*, 371.

[10] This posed a particular problem, as Workman pointed out, for traffic moving eastward across the river.

[11] Minutes of the City Council, 28 April 1921, 122: 458.

[12] Workman, 372.

[13] Workman, 377.

adopt a resolution "determining that the public interest and necessity demand the acquisition and construction by the city of Los Angeles of a certain municipal improvement, to wit: the construction of viaducts or bridges across the Los Angeles River and adjacent railroad tracks, and the acquisition of the necessary lands and rights-of-way therefor . . ." The Council declared that the $1,000,000 estimated cost of the improvements was too great a sum to be paid out of the ordinary annual income and revenue of the city, but the expense was nevertheless necessary if the "objects, purposes and powers" of the city were to be carried out. The resolution, in effect a public notice that there would be a call for bonds, was immediately ordered to be published in the Los Angeles *Daily Journal*. Despite railroad opposition, but with the understanding that the subsidiary street railways would cross the bridges, the city's massive program to build river bridges went on track.[14] Los Angeles now undertook an enormously ambitious program of bridge building, although the Union Station was not completed until 1939.

CHAPTER III. PLANNING FOR THE BRIDGES - 1920-1924

The Power Elite

In Los Angeles, many persons and organizations influenced not only the successful completion of the river bridges, but also their architectural, engineering and aesthetic components. Certainly the business interests represented by the Chamber of Commerce cannot be underestimated, and neither can the input of the Los Angeles City Council that balanced between their role as citizen advocates and the demands of prominent constituents. These politicians paid close attention to neighborhood groups such as the Eastside Improvement Association. The Hollywood Junction Businessmen's Association lobbied for the Glendale-Hyperion Bridge; the ceremony opening Washington Boulevard Bridge was under the auspices of the Washington Boulevard Association and the Vermontshire Association initiated the plan for the Sunset Boulevard Bridge over Silverlake.[15] The *Los Angeles Times'* owners and publishers, Harrison Gray Otis and Harry Chandler, sought to mold and mobilize public opinion for their private interests and to enhance their vision of the city. The Progressives, the City's practicing idealists, had their own particular vision and their most successful years coincided with the simultaneous passage of Bond Acts for the construction and improvement of bridges, harbors and street improvements. These reformers were also the moving force behind the Charter reform of 1924, a year when five City Beautiful river bridges were approved for

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[14] Minutes of the City Council, 28 April 1921, 122: 458; Stephen D. Mikesell, "The Los Angeles River Bridges: A Study in the Bridge as a Civic Monument," *Southern California Quarterly* 68 (winter 1986): 371.

[15] U.S. Department of the Interior, Historic American Engineering Record (HAER) No. CA-272, "Glendale-Hyperion Viaduct," forthcoming, Prints and Photographs Division, Library of Congress. (Hereinafter references to HAER reports will be abbreviated to project number, title, and year of transmittal to the Library of Congress.) HAER, No. CA-284, "Washington Boulevard Bridge," forthcoming; HAER, No. CA-285, "Sunset Boulevard Bridge," forthcoming.

construction.[16] Probably most influential, the Automobile Club of Southern California represented a constituency that was elite, yet growing more numerous and mainstream daily – the motoring public.

Automobile Club of Southern California

Southern California Automobile Club historian J. Allen Davis considered the 1920s one of the "most interesting and active" decades in the Club's history because the policies it pursued to benefit auto-driving members set the organization on a course that would have consequences for all of Southern California for many years to come. As 1920 began, the Board of Directors reelected Fred L. Baker as President of the organization, his eleventh year as President of the organization. Baker's *curriculum vitae* says a great deal about a larger interlocking directorate, the group of powerful men whose interests and civic vision led Los Angeles away from a temporizing approach to civic affairs, and toward their conception of a great metropolis.

Baker had been President of the Los Angeles Merchants and Manufacturers Association, served two terms on the Los Angeles City Council and promoted the Owens River Aqueduct in his capacity as a member of the Municipal Water Board. A powerful force in the city's building and water transportation industry, Baker, owner of Baker Iron Works, had large interests in the Los Angeles Steamship and Dry Dock Company and Los Angeles Lumber Company. The Baker firm handled the construction of the North Broadway Bridge in 1910. Two long-term Directors joined Baker at the monthly dinners of the Board. Joseph Sartori, president of Security Trust and Savings Bank, was the city's most prominent banker and also a director of the Federal Reserve Bank. Davis understated the case when he called Sartori a man who exercised "tremendous influence in the development of Southern California." Harry Chandler, editor and publisher of the *Los Angeles Times*, served on the Club's board from 1913 until his death in 1944. Davis thought it remarkable that Chandler, the Director and Board member of nearly every successful business enterprise in Los Angeles, had time to come to monthly Automobile Club Directors' meetings.[17] Chandler's attendance attests to the power of the Automobile Club and the breadth of its influence. It is hard to imagine that the *Los Angeles Times* publisher could further his interests any better by dining elsewhere.

Auto Club directors, their fellow businessmen, politicians, a clamorous public press, political reformers, and special interests, all ultimately looked in one direction – the city government and its civil servants – to meet their expectations for the infrastructure that would make Los Angeles a better city. The city bureaucracy was generally able, dynamic, and accepted as vital to the public well-being. In the past, it had been city officials and departments who provided organizational stability in a region

[16] Thomas Sitton, *John Randoph Haynes, California Progressive* (Stanford: Stanford University Press, 1992); Kevin Starr, *Inventing the Dream: California Through the Progressive Era* (New York, Oxford University Press, 1985); Starr, *Material Dreams: Southern California through the 1920s* (New York: Oxford University Press, 1990).

[17] J. Allen Davis, *The Friend to All Motorists* (Los Angeles: n.p., c. 1965), n.p.

susceptible to sudden change and disaster: earthquake, flood, drought, boom and bust, bursts of intense growth and successive waves of immigration.[18]

The Department of Public Works had primary responsibility for the city's infrastructure. Traffic movement and congestion were the first problems to be addressed, and the most frustrating bottleneck was the Los Angeles River and the railroads that ran along its banks. Eyes that turned to the Department of Public Works for a solution noted that its Bureau of Engineering had a talented group of bridge engineers anxious to experiment with reinforced concrete arch bridge technology.[19] Yet, the power elite and city planners and engineers were sufficiently farsighted to see that the high water crossings had to be part of an overarching program of traffic control.

The public clamored unceasingly for traffic control, simply because the city continued to grow. In 1900, just over 100,000 people lived in the city limits; in 1910, it was 320,000. Although the population was diverse in origin and evidence of the Hispanic past was unmistakable, migration, mostly white and native born, fueled the growth.[20] The easterners and midwesterners who had sought the sunshine of the city of the angels assumed the leadership of a new Anglo-dominated city. Organizations like the Automobile Club invoked time-honored patterns of American civic participation: form an association and use the force of the membership to influence the politicians.

Major Traffic Street Plan of 1924.

Bridges were essential elements in a scheme of city growth that required an unencumbered roadway to move people quickly and easily to their chosen destinations. Grade separations would prevent delays and accidents at railroad crossings and eliminate cross-traffic and left-hand turns onto major streets. Within the Department of Public Works, the traffic engineers supported the opinions of the bridge engineers: bridges and grade separations were key to continuous, delay-free traffic flow on city streets, across ravines, and over the Los Angeles River.[21]

To get the contentious problem of traffic under control, civic and business organizations set up the Los Angeles Traffic Commission in 1923. Each public-spirited member of its select sub-committee, the Major Highways Committee, subscribed $1000 each to finance the engineering work necessary for the compilation of a comprehensive

[18] Jane Wilson, *Gibson, Dunn & Crutcher, Lawyers*, (Los Angeles: Gibson, Dunn & Crutcher, 1990). William Ellsworth Dunn was Henry Huntington's attorney.

[19] The engineers of the Bureau of Engineering demonstrated their grasp of technology in articles about the theories of bridge design and the techniques of construction. Articles by Merrill Butler and his colleagues appeared in *Western Construction News, Engineering Record, Pacific Municipalities and Southwest Builder & Contractor.*

[20] Roger Waldinger and Mehdi Bozorgmehr, *Ethnic Los Angeles* (New York: Russel Sage Foundation, 1996).

[21] In 1923, the Automobile Club sponsored the organization of the Los Angeles County Grade Crossing Committee. Davis, *Friend to All Motorists*, 85.

street plan for the city.[22] The money funded the employment of three nationally known city planners, Harland Bartholomew, Charles H. Cheney and Frederick Law Olmsted, Jr., to prepare what became the Major Traffic Street Plan of 1924.

Joseph Sartori's Security Trust & Savings Bank of Los Angeles published the plan (with a brief introduction by Executive Secretary G. R. Snethen) in a pamphlet designed as a folded street map, and given away free at each branch location. Referring to the three planners as an "engineering board," Snethen described their work:

> [They] made exhaustive traffic checks and studies, scrutinized carefully every proposed public improvement plan and studied all of the plans of the past of which there were several, and in July 1924, reported back to the Major Highways Committee a definite street plan which would take care of the traffic needs of many years.[23]

At a banquet on 25 July 1924, Bartholomew, Cheney and Olmsted publicly presented their plan to city officials. The Traffic Commission wasted no time in putting the plan before the voters, and in November 1924 it was submitted to the voters as Proposition A on a straw vote. Voters approved the plan five to one, making the Major Traffic Street Plan, according to Snethen, the "official municipal street plan, giving Los Angeles a definite plan by which it could develop its streets into a real, comprehensive street system."

Events proved the Executive Secretary correct. At the same election, a $5,000,000 bond issue, Proposition B, carried with the same lopsided majority. The bond issue enabled the city to finance the construction of 26 streets, the first unit of the Major Traffic Street Plan. By the next summer, the work was nearly complete. Three of the first twenty-six units concerned streets that connected to bridges or were key to bridge development.

- Macy Street (present-day Cesar Chavez Ave.) was continued from the newly completed bridge to Castelar Street, making a connection for traffic moving northwest along the Arroyo Seco to Highland Park and Pasadena.
- Indiana Street was continued from Third Street to First and Anderson Streets, a connection that would ultimately require spanning the ravine by the Fourth Street Bridge over Lorena.
- Washington Street, recommended in the Traffic Plan as a key cross-town connector, was chosen for two projects, both related to the Lorena Street Bridge project. Washington Street (soon to become Washington Boulevard) was to be constructed from Mines Avenue at Lorena Street to Alameda Street and from Alameda to

[22] G. R. Snethen, "Introductory Detailed Explanation," in Traffic Commission of the City and County of Los Angeles, *Major Traffic Street Plan* (Los Angeles: [Security Trust & Savings Bank,] 1924), Collection of the University Research Library, University of California, Los Angeles, back page.

[23] *Major Traffic Street Plan*, back page.

Figueroa Street. The recommendation stated, "provision must be made for viaducts, grade crossings and changing of grades."

Construction was not begun on the Fourth Street Viaduct over Lorena until 1927 due to delays caused by property disputes. Washington Street Bridge, although authorized in 1926, had similar problems and did not come on line until 1931.[24]

The first unit mandated under the Major Traffic Street Plan was completed with such dispatch that the Los Angeles City Council debated the undertaking of a second unit. The method of financing the continued work proved to be a vexatious question with one camp in favor of another bond issue and the other a special tax. The tax advocates won the day, and the voters of Los Angeles approved a nine-cent five-year property assessment to pave and improve the streets. Existing bridges influenced two street projects. The North Broadway Bridge was the catalyst for the widening of Sunset Boulevard to the bridge approach. The Fletcher Drive project, widening York Boulevard to Riverside Drive, mandated the construction of that bridge across the Los Angeles River.

Floating the Bridge Bonds

With the Major Traffic Street Plan nearly completed, on 5 April 1923 the Chamber of Commerce sent a representative to the City Council to request that a proposition for the issuance of bonds to finance river bridges be put on the ballot. At the same time, City Council revisited the issue of railroad participation in the cost of infrastructure improvements, in response to a request by the Traffic Commission. Council noted that conferences had been held between the "city engineering boards" – presumably the Board of Public Works and Engineering – and the railroad companies "to determine the city's proportionate share in the cost of constructing viaducts across the Los Angeles River."[25]

The city's unrelenting growth meant that the construction of the river bridges, developed in tandem with the traffic-driven focus of the Major Traffic Street Plan, was inevitable. Residential development in Boyle Heights and other communities north and east of the river continued, as did the unrelenting outward push for industrial development south along both banks of the river. The 1924 Street plan had also taken into account the construction of major highways to access the agricultural and industrial enterprises outside County borders. No one doubted the need for the bridges, and the City Council resolution was timely and perceptive. The politicians had heard the citizens and knew that the strength of the demand would translate into a willingness to pay for what would be an enormously expensive undertaking. In the next four years the citizens would go in debt for $5,400,000.

[24] "Finding of Adverse Effect. Seismic Retrofit of the Washington Boulevard Bridge" and "Finding of No Adverse Effect. Seismic Retrofit of the Fourth Street Over Lorena Street Bridge," Structural Division, Bureau of Engineering, Department of Public Works, City of Los Angeles.

[25] Minutes of the Los Angeles City Council, 5 April 1923, 135: 278.

Voter enthusiasm for the bridge building program never flagged. The earliest of the twelve historic river bridges were already in place when the campaign began in 1923: North Broadway (1910), North Main Street and Old Seventh Street (1911). Six river bridges, running north to south down the river, were authorized in the bridge bond issue of 1923, passed just before the formal report of the Major Traffic Street Plan: Macy, First, Fourth, Sixth, Seventh and Ninth (Olympic) Street. One river bridge, Spring Street, was mandated in the 1924 issue, as was Fourth Street over Lorena Avenue. Although not a river bridge, the Fourth Street Viaduct was conceived in the Major Traffic Street Plan as part of the traffic flow pattern from the Fourth Street Bridge over the Los Angeles River. Two Los Angeles River bridges would be approved in the 1925 Bond issue, Fletcher Boulevard and the Glendale-Hyperion Viaduct. The 1926 bonds funded the last two bridges: Sixth Street and Washington Street. [26]

An article in the *Mid-Week News Herald* carrying the headline, "More Bridges Mean a Greater City," began the drum-roll for the bridge bond issue of 1925 by stating that traffic congestion was the major problem for Los Angeles. Voters had already adopted one remedy with the Major Traffic Street Plan of 1924. Now public support must continue for bridges and viaducts. Of the three bridges requiring voter authorization in 1925, Glendale-Hyperion, destined to provide a route from Glendale and Pasadena to Beverly Hills and the beach cities to its west, was described as "sadly inadequate, as anyone knows who has had occasion to use the old wooden structure." Fletcher Drive Bridge was needed as a bypass for east-flowing traffic, allowing motorists to avoid the congested downtown; the Mulholland highway bridge would not only relieve congestion in the Mulholland Pass, but connect the presently separated east and west segments of the road, Los Angeles' only scenic mountain drive. Affirming the cooperation between city and county government, the *Herald* reported that the Los Angeles County Board of Supervisors agreed to match the $500,000 dollars of the bond issue dollar-for-dollar if it passed, allotting money from their motor vehicle fund.[27]

The bond issues represented only the City's portion of a program that would eventually cost nearly $17,000,000. That sum included cost of structures, property damage, rights of way, and railway track changes. The County, the railroads and the street railways contributed the remaining costs. The public had done its part; the bridge engineers would complete the work. The task, as bridge historian Stephen Mikesell states, "required a staff unlike any assembled previously in California city government."[28] For the ten year period beginning with the design of Macy Street and ending with the dedication of Sixth Street Bridge, the Bureau of Engineering, responsible for a myriad of public projects, built a set of river bridges that had no equal.

IV. THE BRIDGE DESIGN AND APPROVAL PROCESS

[26] See Annual Reports of the Bureau of Engineering, 1923-1932.

[27] "More Bridges mean a Greater City," *Mid-Week News-Herald*, 2 June 1935, 1.

[28] Mikesell, 379.

The Bureau of Engineering

Works and Days

The 1927-28 Annual Report of the Bureau of Engineering totaled the bill to the taxpayers who had made its program of bridge construction possible:

Election Date	Amount	Purpose
1923	$2,000,000	City's portion of cost of reconstructing six obsolete river viaducts, Macy Street to Ninth Street inclusive
1924	$1,000,000	Renewal of two obsolete wooden bridges, Riverside Drive and Dayton Avenue, and Fourth over Lorena Street, together with construction of Spring Street Bridge
1925	$500,000	City's portion, cost of three new structures including Fletcher and Glendale Hyperion and the Mulholland Highway Bridge
1926	$1,000,000	Further renewal of obsolete bridges and City's portion of Sixth Street and Washington Street Viaducts over the river
Total Amount	$5,400,000	

The five and one-half million-dollar program represented the Bureau of Engineering's budget. This division was responsible for preliminary planning for construction of bridges and special structures, and preparation of designs, plans, specifications and detailed construction estimates. While the Bureau of Engineering had supervision over the construction of the bridges and structures, ongoing and final inspections for approval were delegated to the office of the Inspector of Public Works. The total bridge program by 1928 amounted to $17,000,000 when the cost of structures, property damages, rights-of-way and railroad track changes were factored in. These costs were shared between the City, County, railroads and street railways.[29]

Special assessment districts funded two of the bridges discussed in this report that are not river spans: Franklin Avenue (Shakespeare Bridge) and the Sunset Boulevard Bridge over Silver Lake Boulevard. The character of their respective areas may explain why a special assessment district was easily agreed to by property owners. Franklin

[29] Annual Report of the Bureau of Engineering, 1927-28.

Avenue spanned a deep ravine in the Los Feliz district, a middle-to-upper income neighborhood in the northeastern section of the city. Its Gothic Revival, turreted "Shakespeare" bridge stimulated residential development by providing a roadway link to East Hollywood on the west and the Silver Lake-Ivanhoe District to the east.[30]

Designed in 1933 and opened to traffic in 1934, the Sunset Boulevard Bridge over Silver Lake provided an important grade separation for traffic flowing west on one of Los Angeles' most important and renowned arterials. Sunset Boulevard extended from the downtown core to the Pacific Ocean, and carried the busy Hollywood Pacific Electric red cars as well as auto traffic. Silver Lake Boulevard had figured in several of the earlier City Beautiful Parkway plans and had been called out for special treatment in the Major Traffic Street Plan of 1924. Like the Los Feliz district, the Silver Lake neighborhood, with its rolling terrain and numerous view sites, was destined to develop as a neighborhood of imposing homes. The elegant architectural design of the Silver Lake under-crossing, with its Romanesque arches and cross vaulted ceilings, reflects the influence of the original City Beautiful planning for the parkway as well as the more practical need to keep traffic moving along Sunset Boulevard.[31]

In the depression year of 1931 to 1932, the Bureau of Engineering's Annual Report summed up seven years of accomplishments. In 1923, twelve bridges across the Los Angeles River between Los Feliz Boulevard and the south city boundary had a total of 343 feet of roadway width and forty vehicle traffic lanes. In 1932, counting three early bridges still in place, nine reconstructed, and four added, fifteen bridges within these boundaries had a total of 860 feet of roadway width and ninety-three traffic lanes. Of fourteen "very dangerous and very busy" railway grade crossings, only four remained, the others having been eliminated by the bridge reconstruction or replacements. The report asked readers for a backward glance into the past:

> While it is very easy to enjoy conditions as they now exist and to speed across the viaducts with little thought of the past, yet it will not be difficult for those who were residents of the city in or prior to 1923 to recall the long delays at such bridges as Ninth Street, Macy and Seventh Street where the train movements were particularly heavy; nor to recall the long lineup of traffic [in the] evenings and on holidays waiting to cross the narrow bridges at Glendale and Los Feliz Boulevard... The new viaducts are constructed to provide as much or more traffic capacity than that of the connecting street, and "bottlenecking" of traffic at these structures cannot occur again.

While the City Engineer may have anticipated that city traffic would continue to outgrow capacity as the year went on, he and his staff quite evidently took satisfaction in knowing that the citizens enjoyed the wide roadways, the saving of time and the

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[30] The Los Feliz neighborhood in its early days was associated with the Walt Disney studio, located at the intersection of Griffith Park and Hyperion Boulevards. Houses with a distinctive "story-book" style were constructed nearby, including Disney's own house two blocks from the Shakespeare Bridge.

[31] Los Angeles Park Commission, *Silver Lake Parkway: A Brief Discussion of the Proposed Silver Lake Parkway*... (Los Angeles: Los Angeles Park Commission, 1912); "Paving of Important Silver Lake Boulevard Link Reported Assured by City Council," *Los Angeles Evening Express*, 22 May 1926, 25.

avoidance of danger at railway grade crossings. The viaducts themselves, he noted, had taken their place among the "sightly" structures of the city.[32]

Builders and Designers

In his overview of highway bridges in California, bridge historian Stephen Mikesell points out that California was particularly fortunate in having state and municipal employees with the expertise to design and build their own bridges. Mikesell singled out the City of Los Angeles not only for its "ambition" in solving the problems necessitated by the nature of the river and its course through the heart of the city, but also by its ability to integrate architecture and aesthetics:

The staff of the Los Angeles Bureau of Engineering embarked in the mid-1920s on one of the most ambitious programs ever undertaken by an American municipality and produced some of the most beautiful and substantial bridges to be found in California.[33]

A brief historical sketch of the Bureau indicates the caliber of its personnel during the period between 1907 and 1915. Between these years, Los Angeles changed the governmental structure it had inherited from the Hispanic past into a civic power structure reminiscent of the Anglo cities in the east and mid-east that the new immigrants had once called home. By 1933 the United States was in Depression, and the intense spurt of growth and building that had sustained the city for a quarter-century had slowed. The Bureau did not take up a similar bridge construction until the Bureau of Engineering undertook an immense program of bridge seismic retrofit and restoration in 1990.

In 1900, when Los Angeles' influential business newspaper the *Daily Journal* sent out the call on page one for "sightly and durable" bridges, many of the wood and iron steel trestle bridges were built by the railroads, developers, or private owners of industrial lands. The *Journal* called for the use of concrete or stone, citing bridge engineers' judgment that the costs would not exceed those of steel.[34]

In 1905 the City Charter was amended, establishing a three-member Board of Public Works. The Mayor appointed board members who were confirmed by the City Council. Public Works' enabling ordinance forbade more than two members from the same political party. The duties of the Board included appointing a City Engineer with a qualification of five years minimum experience, and approving the various projects of the engineering department. Homer Hamlin was appointed in 1906. A professional of vision and determination, he was not afraid of the challenge. In his first *Annual Report* to the City Council at the end of the year, he advocated the use of reinforced concrete for the Macy and Seventh Street Bridges. This action clearly signaled the Bureau's intent to

[32] *Annual Report of the Bureau of Engineering*, 1931-1932.

[33] Stephen Mikesell, *Historic Highway Bridges of California*, (Sacramento: California Department of Transportation, 1990), 4.

[34] "Need Better Bridges. Structures Should be Artistic as well as Substantial," *Los Angeles Daily Journal*, 16 Mar. 1907, 1.

answer the public call for high-water, unobstructed crossings over the Los Angeles River.[35]

Hamlin's career must be seen in the context of how the role of the Los Angeles Public Works bureaucracy changed at the turn of the century. Changes in the City Charter in 1906 made the post of City Engineer appointive rather than elective. In addition the new charter made the Engineer responsible to a new five-member Board of Public Works. It was Hamlin's lot to work through both organizational modes.[36]

Born in Minnesota in 1864, Hamlin came to California in 1886 after one year of college and a stint as a schoolteacher. After his arrival he traveled and worked in Southern California as a civil engineer and surveyor. In 1899 the elected City Engineer, Frank Olmstead, appointed Hamlin Chief Deputy over all field forces. He remained in the post for three years, then left to work on the Yuma water project on the Colorado River for the United States Reclamation Service. William Hansen, historian for the Bureau of Engineering, speculates that Hamlin did not relish the political fight necessary to obtain an elected office. However, with the sudden death in 1906 of City Engineer Harry F. Stafford, Olmstead's successor, the Council turned to Hamlin, requesting that he take the City Engineer's job. Hamlin served for eleven years, resigned to go into private practice, and died three years later in 1920 at the age of fifty-six.[37]

The beginning of Hamlin's tenure coincided with the planning for the three original reinforced concrete bridges over the Los Angeles River. He appears to have been very influential in their development. Hamlin added comments to Charles Mulford Robinson's City Beautiful plan that had been commissioned by the Municipal Arts Commission of the City. In that addendum, Hamlin admitted that he had not only opposed the Board of Public Works when they recommended "cheap wooden bridges" but delayed the building of the Buena Vista Viaduct by "obstinacy." The City Engineer had demanded that the railroad grant space for bridge piers in the railroad yards so he and his engineers could build an all-concrete arch bridge, instead of a "long, ugly steel truss span over railroad tracks, which was first regarded as a matter of course."[38] In that piece Hamlin set down the governing principles that would guide river bridge building for the next twenty-five years:

> It is now the policy of the Board of Public Works to recommend cheap wooden bridges only in outlying districts and occasionally for more important crossing where a temporary bridge can serve the purpose until funds are available for a more pretentious structure... At all main thoroughfares, however, when an old bridge is outgrown, a new one is designed with three objects in view - namely to

[35] Annual Report of the Bureau of Engineering, 1906, Los Angeles City Archives.

[36] City Charters of Los Angeles, year by year compilation, Los Angeles City Archives.

[37] William Hansen, "The Rearview Mirror - 75 Years Ago," *Engineering Newsletter*, n.d., n.p. On file, Environmental Management Division, Bureau of Engineering, City of Los Angeles.

[38] Homer Hamlin, "Bridge Construction in the City of Los Angeles," addendum to *The City Beautiful: Report to the Municipal Arts Commission* (Los Angeles: William J. Porter, 1909), n.p.

make it permanent, adequate for possible future needs and, at the same time, sightly. The aesthetic side is taken care of by adopting the arch form and by special treatment of the concrete surfaces. On each side is built an ornamental stone balustrade with lighting posts over the piers and other architectural ornamentation is employed in keeping with the character of the structure.

There is little in the record to indicate the direction of policy under Hamlin's immediate successors, Andrew C. Hansen (1917-1920) and John Alden Griffin (1920-1924). Since Griffin's tenure coincided with the passage of the bridge bonds in 1923 and 1924, it seems apparent that he must have been active in gearing up his staff in the design and construction of the six river bridges authorized in the 1923 issue. Griffin's successor Harvey Van Norman (1924-1925) served only a year, resigning to succeed William Mulholland as Chief Engineer of the Bureau of Water Works. The next two office holders presided over the completion of the work: John C, Shaw (1925-1931) and J. J. Jessup (1930-1933).[39] It was an impressive tally: Olympic Boulevard in 1925; Macy Street and Franklin Avenue Bridges in 1926; Fletcher Drive Bridge in 1927; North Spring Viaduct in 1928; Glendale-Hyperion, 1929; 4th Street Viaduct, 1930; Washington Boulevard Bridge in 1931; 4th Street Bridge over Lorena Street in 1928; Glendale Hyperion in 1929; 4th Street Viaduct over the Los Angeles River, 1930; Washington Boulevard Bridge in 1931. Every single one satisfied Homer Hamlin's requirements. They were reinforced concrete, open spandrel, arch bridges, planned to be permanent for future needs and ornamented in keeping with their design style. Washington Boulevard Bridge was the only girder span bridge, but it was ornamented with the tall pylons characteristic of the others. Each of the four pylons on the deck carried an elaborate terra cotta tile frieze which exhibited bridge engineers and workmen with their tools engaging in bridge building; this was a spectacular and appropriate paean to the immense effort expended by the Bureau in putting the river bridges in place.

Merrill Butler

The breadth of the undertaking is underscored by the efforts of the design engineers whose plans and drawings gave the bridges their character and monumentality. Principal among them was Chief Engineer of Bridges Merrill Butler. Butler committed forty years of his life to the Bureau, being employed from 1923 until 1963 when he retired at the age of seventy. Beginning as drafter under Homer Hamlin, he worked up through the ranks. His writings on the individual bridges indicate a solid knowledge of every facet of bridge planning and design. He wrote few articles, but articles in trade journals such as *Western Construction News* demonstrate a solid grounding in engineering, mathematics and construction techniques. He usually organized his articles

[39] John P. Hunt and Bernice Kimball, *City of Los Angeles: City Engineers, 1855-1981* (Los Angeles: City of Los Angeles Board of Public Works, 1982).

by explaining the planning involved, describing to the reader why the design decision in question had been chosen.[40]

Although no departmental records are available, it is clear from reading the bronze plaques that appear on the individual river bridges that Butler headed the design team. On the earlier bridges he is frequently identified as "Bridge Engineer"; on later dedication plaques he is variously identified as Chief of Engineers or Engineer of Bridges and Structures, apparently depending on his departmental title, or the person responsible for the text on the plaque.

Also given credit on most of the bridge plaques is H.P. Cortelyou, usually identified as "Construction Engineer". Cortelyou was a college trained engineer on whom Butler relied for construction expertise. Assistant Engineer of Bridges and Structures was H. H. Winter who contributed articles on the First Street Viaduct, Washington Boulevard and Sixth Street Bridges to *Western Construction News.*[41] Another member of the team that reported on the bridge building process was Louis L. Huot, who seems to have specialized in architectural ornament and lighting. Huot contributed short, non-technical articles on Sixth Street Viaduct.[42]

The success of the bridge building program, the overall community satisfaction it generated, the quality of the writing on the various bridge projects, as well as its appeal to both general and professional audiences, argues that the city of Los Angeles was fortunate indeed. Within the Bureau of Engineers worked a talented and inspired group of engineers and architects, whose chiefs, the City Engineers, led a team effort to provide the crossings that brought Los Angeles citizens the convenience, confidence and prosperity characteristic of the decade in which they produced their monumental river crossings.

Municipal Arts Commission

The final link in the bridge building process was the Municipal Arts Commission. Organized in 1903, the Commission was given official status when the Los Angeles City Charter of 1911 provided for a Department of Municipal Art. The enabling ordinance made the Commission powerful and influential in the cultural life of the city. Without a majority vote of the Commissioners, the City could not receive or purchase a work of art, or place it in any park or other public place. If the Commission wished, it could require the architect or public agency designing a public building or other structure to submit a complete plan to them. Unless the Board approved the plan, it could not be carried out.[43]

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[40] Merrill Butler, "Architecture and Engineering are Harmonized in Fourth Street Viaduct," *Southwest Builder and Contractor* (7 Aug. 1931): 49-50; Butler, "Sixth Street Viaduct, Los Angeles," *Western Construction News and Highway Builder* (10 July 1932): 385-391.

[41] H. H. Winter, "First Street Viaduct, Los Angeles," *Western Construction News* (25 Nov. 1927): 36; Winter, "Washington Street Bridge and Sixth Street Viaduct for Los Angeles," *Western Construction News* (25 Apr. 1930): pages?.

[42] Louis L. Huot, "Lighting the Sixth Street Viaduct," *Western City* (July 1933): 19-20; Huot, "Modern Lines Are Reflected in New Los Angeles Viaduct," *Architect and Engine*er (Oct. 1933): 25-30.

[43] "New Municipal Art Commission," *Southwest Contractor and Manufacturer* (26 Aug. 1911): 17.

In 1909 they hired Charles Mulford Robinson to create a plan for the beautification of Los Angeles. Robinson was the author of twenty-five municipal improvement plans throughout the United States, and the premier advocate of City Beautiful planning, a comprehensive effort to improve and humanize cities through the creation of scenic boulevards, gardens, infrastructure, and monumental architecture. The architectural style favored by the City Beautiful movement, monumental Beaux-Arts Classicism, was designed to make a grand and elegant building statement. Robinson stressed the idea that beauty and utility could not be separated. "A bridge," he said, was so "monumental a structure that we should not be satisfied merely with durability and strength, but should demand that to these be added fitness, grace and beauty."[44]

The Commission, in the best bureaucratic spirit, was not unwilling to enhance its power. In 1926 it asked for special authority from the City Council to evaluate designs proposed for privately owned buildings facing the civic center, in order to prevent the erection of structures that would depreciate the value of the government buildings. While the Commission had absolute veto power over a design, there was one restriction on their power: the heads of city departments were ex-officio members, but had the power to vote.[45]

In the years 1923 to 1929, Los Angeles River Bridge designs were submitted to the Commission for approval. The Commission introduced its 1924 report with the following summary:

> During this year, the Municipal Art Commission has continued to demonstrate its value to the City in promoting more suitable architecture for civic structures, thus insuring that they conform to a type of architecture and design adapted to the particular building and representative of a civic structure.[46]

1924 was a busy year for the Commission, as they vetted 618 plans for structures totaling $11,540,810 in assessed valuation. The report noted that some plans were resubmitted for correction "either on account of corrections necessary to make them conform to simple lines of architectural beauty or because of changes in design."[47] The committee eventually passed on all the bridges. Among their approvals in 1924 were plans for Macy Street and Ninth Street (Olympic Boulevard) bridges. In the following year, these viaducts themselves were approved with commendations.

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[44] Robinson, *City Beautiful*, 3.

[45] The five appointed members of the Commission usually included at least one architect, usually two women, often artists, or wives of architects. The film industry generally had a sitting member. Between 1921 and 1928, Sid Grauman and Mrs. Cecil B. De Mille were appointees. This representation is not surprising since the industry was engaged in a program of building monumental movie theaters. The President of the Commission during the years of active bridge building, F. W. Blanchard, served for 21 years. See Municipal Art Commission, *Annual Reports, 1921-1929,* [City of Los Angeles, 1930].

[46] Municipal Art Commission, *Annual Reports, 1921-1929,* n.p.

[47] "Municipal Architecture Carefully Censored," *Southwest Builder and Contractor* (19 Sept. 1924): 46.

In 1928, after approving Washington Street Viaduct, the Commission gave a special commendation to the Bridge Division of the Bureau of Engineering "for interest shown in providing excellent designs for viaducts and other structures." In the course of the year's report, the Commission also gave itself a commendation, remarking that since applicants knew they had to pass the Commission's standards, they made greater efforts to provide well-designed buildings. City departments, they reported, showed a commendable spirit of cooperation by submitting numerous preliminary sketches.[48]

These pronouncements offer one of the reasons for the high quality of design and architectural detail characteristic of Los Angeles monumental bridges. The members of the Municipal Arts Commission did not simply function as an architectural review board. Men and women with educated tastes, professional training, experience and status in their field, the Commission members first emphasized the Beaux-Arts ideals of the City Beautiful movement. In later years they progressed to allow a cautious modernism into their architectural and aesthetic vision for Los Angeles civic architecture and were not reluctant to impose their standards through the approval process. By analyzing bridge plans in preliminary phases they subtly, or perhaps consciously, directed the design. The results of their deliberations some seventy-five years ago appear today in the artistry and ornament of each bridge design submitted to them. Beginning with the Beaux Arts North Broadway Bridge in 1911 and concluding with the Art Deco inspired Washington Street Bridge in 1931, the bridges over the Los Angeles River, defined by their ornamentation and attention to detail, became public expressions of civic pride.

CHAPTER V. DESIGN AND CONSTRUCTION OF THE LOS ANGELES RIVER BRIDGES

Timeline of Reinforced Concrete Bridge Construction

1808- In England Ralph Dodds receives the first patent for reinforced concrete.

1824- Joseph Aspdin invents Portland Cement.

1840- A 39-foot mass concrete bridge is built over the Garone Canal in France.

1867- Joseph Monier experiments with wire mesh reinforcing for concrete.

1872- W. E. Ward establishes the need to reinforce the lower tension edge of concrete beams.

1877- T. Hyatt publishes a method for determining the stresses on the top and bottom surfaces of reinforced concrete beams and slabs.

[48] Municipal Arts Commission, *Annual Report, 1928.*

1889- Lake Alvord Bridge in Golden Gate Park, is the first reinforced concrete bridge built in the U.S. Designed by E. L. Ransome, it featured twisted reinforcement bars.

1892- Melan System of steel I-beam reinforcement cast in concrete is patented.

1893- American Society of Civil Engineers publicizes Melan System in the U.S., after which it becomes a standard for early reinforced concrete construction.

1894- Pont de Chatellerault, a Hennebique-designed bridge in France, is an early long span (172 feet) reinforced concrete arch bridge.

1897- Maillart designs a three-hinged arch bridge, the Stauffacher Bridge in Zurich.

1905- Maillart designs a three-hinged, open-spandrel arch bridge with a 167-foot span, the Taranasa Bridge in Switzerland.

1906- Santa Cruz Bridge in California is the first three-hinged arch bridge in California to use the patented Thomas system.

1909- Robinson publishes *The City Beautiful.* Reinforced concrete bridges are widely accepted in U.S. engineering practice.

1910- The first group of reinforced concrete bridges in Los Angeles is constructed: Buena Vista Bridge (North Broadway Viaduct); North Main Street Bridge; and the Seventh Street Bridge.

1911- Freyssinet experiments with pre-stressing reinforced concrete.

1920- Invention of concrete vibrating by Freysinnet, creating strong and dense concrete.

1923- Bridge construction bond passed by Los Angeles voters. The remainder of the bridges documented in this recording project were built between 1923 and 1934.

Significance

The fifteen structures studied in the Los Angeles River Bridges Recording Project represent four bridge construction types, though the reinforced concrete, open-spandrel, ribbed-arch design is the most common. Built between 1910 and 1934, the bridges are a record of the changes in bridge building technology and the political, economic, and cultural life of the residents of Los Angeles. Considering the major transportation issues faced by Los Angeles in the early decades of the twentieth century, these bridges were innovative design solutions as well as crucial links in the metropolitan transportation system. While each of the bridges exhibit design features that contributed to the general development of reinforced concrete in bridge design, the bridges as a group represent one of the most significant urban transportation viaduct systems built of reinforced concrete in the early years of the twentieth century. The bridges of this recording project, all variations on reinforced concrete construction, were built in two distinct time periods.[49] North Broadway Viaduct, North Main Street Viaduct, and the lower bridge of the Seventh Street Viaduct were opened in 1910. The rest of the bridges were built between 1925 and 1934. Ten of the fifteen bridges are reinforced concrete, open-spandrel, ribbed-arch construction. Of the early bridges, the North Broadway Viaduct and the North Main Street Viaduct were both reinforced concrete, open-spandrel, arch bridges. Seventh Street was closed-spandrel. Two of the later group of bridges, Fletcher Avenue Bridge and Washington Boulevard Bridge, are simply supported reinforced concrete girders. The Sixth Street Viaduct is a unique combination of steel arches with reinforced concrete decking and approaches. The Seventh Street Viaduct is a combination of two bridges, a 1910 reinforced concrete closed spandrel arch with a 1927 simply supported reinforced concrete bridge built on top of the earlier span. The final bridge in the project, Sunset over Silverlake Bridge, is constructed of riveted steel plate girders on reinforced concrete piers. The Los Angeles River bridges were significant engineering works and at the cutting edge of technology at the time of their construction. Each of the bridges exhibited advances in the engineering practice of designing and constructing long-lasting reinforced concrete bridges, and the engineers of the City of Los Angeles advanced the engineering practice of using reinforced concrete.

The Innovation of Reinforced Concrete

Reinforced concrete is the combination of concrete and steel. Concrete is strong in compression, whereas steel in strong in tension. The combination of the two materials creates a composite material that is suited to many construction projects. The coefficient of expansion of concrete and steel are nearly the same, allowing the two materials to be bonded and remain interlocked through temperature changes. Additionally, the concrete protects the steel from the elements. Concrete is made by mixing cement with sand, crushed rock, and water. After the cement combines chemically with the water to form a cement paste matrix around the sand and crushed rock, or aggregate, the paste gradually hardens.

The gradual hardening of the concrete created two problems that the Los Angeles River bridge engineers addressed in their designs. First, when concrete hardens there are volume changes known as shrinkage. Second, the concrete is under load (its own weight) as it gradually hardens, causing water to be squeezed out of the pores of the material.

[49] Sunset over Silverlake Bridge is the exception. See the HAER histories for the details of the individual bridges.

This water seepage results in a gradual reformation of the concrete, a process known as creep.

The timeline at the beginning of this chapter lists some of the milestones in the development of reinforced concrete, and the history of its application to bridge construction. The first concrete bridge was built in France in 1840. It was a 39-foot long structure that was made of mass-poured, un-reinforced concrete. Nearly fifty years later the first reinforced concrete bridge in the United States, the Lake Alvord Bridge, was constructed in San Francisco. The story then shifts to Europe where engineers created innovative designs for reinforced concrete bridges at the end of the nineteenth and the beginning of the twentieth century.

Engineers in France, Switzerland and Sweden led the way in the design and construction of reinforced concrete bridges. Their work and research influenced the design and construction of bridges in the United States, particularly the river bridges of Los Angeles. Robert Maillart is one of the most famous reinforced concrete bridge designers of the twentieth century. His understanding of the structural potential of the medium made many of his bridges milestones in bridge engineering history. Nearly all of Maillart's bridges exhibit a purity and elegance of line, devoid of superfluous ornamentation, that is unrivaled to this day. Two engineers who had a major influence on his work with reinforced concrete were G. A. Wayss (1851-1917), a German engineer, and Francois Hennebique (1842-1921), a French engineer, with whom Maillart collaborated in the 1890s.[50] These men had proved that reinforced concrete was economical and could be used in place of more traditional materials such as wood, stone, and even steel. Wayss worked with reinforced concrete arches, making the arches massive and solid, mimicking stone arches and adding large safety factors to his load calculations. Hennebique used reinforced concrete as one would use wood and steel, in columns and beams. Maillart gained both an understanding of the material properties of reinforced concrete, and how these properties affected the construction of reinforced concrete bridges.

The Stauffacher Bridge, designed in 1898, is an early Maillart bridge. The bridge features a three-hinged arch, with a hinge in the arch crown, and hinges in the two supports for the arch. This three-hinged design was used extensively in the Los Angeles River Bridges. In Maillart's design the hinges were free to rotate in the vertical plane, and at these points the arch has no resistance to bending. This design has two major advantages. First, as the arch expands and contracts with changes in temperature the hinge allows bridge movement without cracking. Second, the three-hinge design makes the engineering calculations much simpler, meaning greater confidence in the results. This bridge design was not standard engineering practice at the time.

Many engineers used a method for reinforced concrete calculations based on Hooke's Law, which states that in an elastic material, load is proportional to deformation. Both Maillart and Freyssinet carried out tests that determined that due to both shrinkage and creep, concrete demonstrated behavior that was not predictable by Hooke's Law. Thus, to create simple structural systems where factors such as shrinkage and creep were

[50] Maillart worked on a sanatorium for which Hennebique was the consultant for the concrete work.

reduced to a minimum, Maillart aimed to account for shrinkage and creep in his bridge designs. The three-hinged arch design met these criteria. Maillart continued using this design over the years, and his work influenced bridge design in the United States and California.

Reinforced Concrete Bridge Construction in California

Californians made many innovations in reinforced concrete technology in the first half of the twentieth century and built many monumental bridges using the material. The Los Angeles River bridges are a significant set of many examples statewide. Concrete bridges are more numerous in California than elsewhere in the United States.[51] This is due to both the historical high cost of steel in California in the early twentieth century, and the high-quality, low cost cement that was available. E.L. Ransome designed the Alvord Lake Bridge in Golden Gate Park, the first reinforced concrete bridge in the United States, in 1889. Ransome, a San Francisco engineer, had been experimenting for years with reinforced concrete. Among his patents were an expansion joint for concrete sidewalks, and a twisted steel reinforcement bar.[52] The Alvord Lake Bridge was the first in the nation to use the twisted reinforcement bar, thus pointing the way to the predominant twentieth-century method. The Lake Alvord Bridge is also an example of reinforced concrete bridges. At this early date reinforced concrete had not come into its own as a material, with its own material expression. Instead, the material, because of its plastic qualities, was made to look like stonework, complete with stalactites under the bridge.

For the most part, California's reinforced concrete bridges were designed by Californians. One of the early innovators of reinforced concrete bridge design in early twentieth century California was W. M. Thomas. He refined and popularized the three-hinged arch design pioneered by Maillart that was used in many of the Los Angeles River Bridges. Thomas trained as an architect at the Chicago Art Institute, and then worked as a structural engineer for the railroads. In 1906 Thomas moved to California to work for the Union Traction Company, an interurban line in Santa Cruz. He designed the first three-hinge reinforced concrete arch bridge built in California, the Santa Cruz Bridge, in 1907. Three-hinge arch bridges were familiar in Europe, but only two had been built in the United States prior to Thomas' work, one in Cleveland and the other in Denver. The Santa Cruz Bridge served as the basis for the development of what Thomas heavily promoted as the "Thomas System of Three-Hinge Arch Bridges." In 1902, Thomas founded his firm of Thomas and Post in California, after studying European, particularly German, use of the three-hinge arch design.

The Thomas System featured six patented principles that were used in bridge construction. First, the concrete arch ribs were poured on the ground, giving the builders more control and arguably simplifying the construction of the formwork. The ribs were then hoisted into place, resting on piers or abutments and meeting at the center or crown.

[51] Mikesell, *Historic Highway Bridges*, 71.

[52] The Melan System, an industry standard, featured much larger steel I-beams.

Spandrel posts and floor slabs were also poured on the ground and hoisted into place. A hinge was used at the crown of the arch, eliminating, according to Thomas, internal temperature strains that cause cracking in fixed-type arch bridges. By reducing these strains, the amount of concrete and steel required in the bridge was also lessened. Thomas expounded this process in the engineering literature of the day.[53]

The hinges in Thomas' design allowed reinforced concrete bridges to be built safely where abutments could not be placed on bedrock or other satisfactory material, a feature that was significant for the Los Angeles River Bridges because they were built over riverbeds. "Abutments and piers for this type need not be considered as absolutely fixed and without settlement," he wrote.[54] The reinforcement in the bridge was a steel formwork of straight members attached at their ends, causing the bridges to act as a rigid body around the hinges. Thomas also patented this reinforcement design. In a properly designed arch, argued Thomas, the arch is always in compression, making reinforcing unnecessary. Reinforcing is present, he added, to aid strength in compression, to take up eccentric forces, and to insure safety in hoisting the arches into place. Thomas also argued that his system resulted in a twenty-five to thirty percent cost savings over conventional arch bridge construction.

Savings were to be realized in the steel and concrete required, and in the amount of labor and lumber saved with the elimination of all centering. Thomas was not, it seems, involved directly in the design and engineering of any of the Los Angeles River bridges. His system, however, was widely published in the engineering and construction literature of the time, and his research and construction methods were utilized in the design of the river bridges.

Design and Construction of the Los Angeles River Bridges

The engineers of the City of Los Angeles favored reinforced concrete in the early years of this century, as did engineers throughout the country. Thomas was but one innovator nationally, but a significant one for California. The Los Angeles engineers found reinforced concrete bridges, particularly the three-hinge arch design, to be economical, durable and advantageous for constructing river crossings. Reinforced concrete was a material especially suitable for arch spandrel designs and bridge deck ornament, inspiring the grand public monuments over the river, which proclaimed the progress of the city to the rest of the country and the world.

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[53] W.M. Thomas, "The Thomas System of Three-Hinge Arch Bridges," *Southwest Contractor* (14 Apr. 1914): 9.

[54] Ibid.

The primary concern for the city engineers was the Los Angeles River itself, a flow to be avoided and a dry bed to be crossed. Each year the river transformed from a nearly dry channel in late summer and early fall to a debris-filled torrent after winter storms. Its unpredictable flooding and shifting sands and gravel made fixing the locations of firm foundations, piers, and abutments a very difficult task. River scour, the rock and debris collected and pushed down the river channel by raging waters, was a threat recognized by bridge engineers. Additionally, the Los Angeles River was being mined by city contractors for sand and gravel for construction throughout the city. At many locations along the river the mining had substantially deepened the channel, and caused even greater unpredictability. This "river bed mining" threatened the piles supporting bridge foundations. Eventually this practice was made illegal.

The nature of the Los Angeles River, as well as the ever-present earthquake threat, made the three-hinge arch bridge the most desirable engineering solution for bridges. Thomas promoted it in situations of excessive settlement or foundation spread, maintaining that under conditions of "earthquake disturbances, the hinge allows the bridge to automatically adjust." The hinge, it was believed, prevented forces from materially affecting the stresses in the arch ring. Engineers employed the three-hinged arch for the first group of the Los Angeles River Bridges completed in 1912, as well as several crossings in the next decade.

After establishing the basic design, including the riverbed foundations, the engineers created a construction process that was followed generally but varied in specifics for each bridge.[55] The general process began with the construction of formwork for the arches and girders. The formwork required the engineer to create elaborate plans so carpenters could build it, and represented a significant cost. On many of the bridges the formwork was built in such a pattern that it could serve as the finished surface on the completed bridge. This finish detail can be seen beneath the Main Street Bridge. On some arch bridges the cost of the formwork was reduced by nearly half by pouring one side of the bridge, waiting for the concrete to cure, and then sliding the centering over for the other half.[56] The concrete was most often mixed on site at a batching plant. In some instances cranes had to lift hoppers full of concrete up to the bridge pour. Other times the batching plant was built alongside the bridge and hoppers were suspended from overhead cable lines to reach the desired pour site. Once the arches were set, concrete spandrel columns were poured. Then decking was poured between the abutments and the deck support structure. The last step was to complete the architectural details, including light fixtures, railings, and ornament.[57]

Both North Main and Fourth Street present important variations of the three-hinge arch design. In 1910, the completed North Main Street Bridge was described in *Southwest Contractor and Manufacturer* as "a type, known as the three hinged

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[55] H.G. Parker to Homer Hamlin, 30 Nov. 1908, in Annual Report of the City Engineer, Los Angeles City Archives, 2.

[56] The Macy Street Bridge (Cesar Chavez) and the 9th Street Viaduct (Olympic Boulevard) are examples.

[57] For information on this process, see Heather Larson's drawing #1 in HAER, No. CA-172, "Dry Creek Bridge," 19xx.

ribbed arch, never before used in the Southwest and rare in the United States, though in somewhat common use in Europe, where it has proved meritorious."[58] Designed by H. G. Parker and Homer Hamlin, the bridge was distinct from Thomas bridges. Thomas poured and set the ribs on the ground and then erected them as isometric hinges. Parker and Hamlin's arch ribs were poured in place with the hinge areas left open, to be filled with concrete after the centering was removed. The hinges, described as compressible joint hinges, were then converted into joints using batten and felt. The compressible joint hinge predominated in European designs. While the three arches in this bridge were only 87.5 feet in length each, the three-hinged construction was seen as providing advantages by limiting the amount of moment from the dead load, while allowing for movement of the arch ribs. The design focused on minimizing the moment, and minimizing stresses introduced by shrinkage and creep.[59]

In 1931 the 4th Street Bridge was described as using "temporary hinges." Thought to be the first bridge of its kind in the United States, it used a temporary hinge common in Europe. The Fourth Street Bridge hinges were nineteen-foot spiral coils within a concrete core. The hinges had the advantages of relieving stresses induced by movement of the abutments, shrinkage of the concrete during curing, change in the shape of the arch with dead loads, and high initial temperature of concrete during curing, which would induce shrinkage with cooling. This design was chosen for the Fourth Street bridge with an open spandrel arch of 254 feet to minimize stresses that were greater than those within the Main Street arches of 87.5 feet.[60]

Beyond variations in hinge design, the City engineers were involved in experiments to improve the performance of construction materials. H.P. Cortelyou published technical papers on the methods used by the engineering department of the City of Los Angeles to improve the quality and strength of concrete in bridge construction. A four-year study by the Bureau of Engineering found that the strength of concrete had been improving remarkably. As Cortelyou argues "I feel that the increase of strengths have been largely accomplished by our studies in gradings of the local aggregates to obtain a combined coarse aggregate of maximum density. Most careful consideration has also been given to the water cement ratio." [61] He goes on to state that

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[58] "A Three-Hinged Ribbed Arch Concrete Bridge," *Southwest Contractor and Manufacturer* (7 May 1910): 16.

[59] "A Reinforced Concrete Bridge Built in Sections on the Ground," *Southwest Contractor and Manufacturer* (4 Mar. 1911): 18; "Three-Hinged Ribbed Arch Concrete Bridge," 17; *CalTrans Arch Bridge Rating Sheet, Bridge # 53C-1010*, 2 June 1986, Collection of the California Department of Transportation Library, Sacramento, Calif. See Jason Currie's drawings in HAER, No. CA-276, "Main Street Bridge," forthcoming, for illustrations of shrinkage, creep, and a further explanation of the three-hinged arch and its construction.

[60] "New Method of Arch Rib Construction Feature of Fourth Street Viaduct," *Southwest Builder and Contractor* (24 Apr. 1931): 46-47; Merrill Butler, "Architecture and Engineering are Harmonized in Fourth Street Viaduct," *Southwest Builder and Contractor* (24 Apr. 1931): 50.

[61] H. P. Cortelyou, "Strength of Concrete in Bridge Construction at Los Angeles," *Western Construction News* (25 Apr. 1928): 270.

strength is but one factor being studied. The others are density, impermeability, and surface finish. The work of other experimenters, such as J. J. Jessup, the City Engineer of Los Angeles, who detailed the effects of unsound aggregate on concrete in Western Construction News in 1931, was also featured in the engineering journals of the day.[62]

Seismic Issues

In the early years of the twentieth century, river bridge engineers became increasingly conscious of seismic activity in the Los Angeles Basin, but little research was available to give much information regarding seismic design to engineers. As a result the Los Angeles River bridges met standard engineering practice of the time, but exhibited only modest innovative seismic design features, if any at all.

While the San Francisco earthquake of 1906 received great coverage and seismology received profound attention, only after many years of research were new approaches to structural design developed. The great earthquakes of the 1920s, including the 1923 Tokyo quake, the 1926 Santa Barbara quake, and the 1927 Calexico quake focused the attention of structural engineers on seismic design. Japanese scientists and designers led the research, with Fusakichi Omori's shake-table experiments providing a basis for the classification of earthquake movements, as well as inventing terms and definitions for seismic discourse. In 1928 Stanford University constructed a shake table that allowed researchers to observe structural responses to movements. Seismology as a science, though still in its infancy, gave engineers a starting point for developing structural design principles. The main dilemma, which continues as a design choice today, was whether to design structures to respond in a flexible or rigid manner.[63] Flexible structures, it was believed, would allow seismic activity to move a structure without the structure failing. Rigid structures would be strong enough to withstand seismic forces. With the Los Angeles River Bridges, the engineers most often made the decision to use the three-hinged arch design, providing flexibility for both the foundations in the riverbed, and for seismic activity. This design decision, however, has been reversed in much of the retrofit design of the 1990s.

Los Angeles did not lead the advances in seismic design for California. Santa Barbara, San Francisco, Palo Alto, and Sacramento preceded Los Angeles in developing building codes for earthquakes. Some of the early design approaches were based on theories developed for wind loads, but others were more particular to the forces of an earthquake. Based on prior earthquakes, it was felt that the value of acceleration .1g (ten percent of gravity), or 3.2 feet per second, was the general condition that would be experienced by buildings during a seismic event in the United States. However, this assumed that the structure was located several miles from a fault. General design recommendations discouraged the location of structures on marshy soils or on active fault

[62] J. J. Jessup, "Effect of Unsound Aggregate on Concrete," *Western Construction News* (10 Sept. 1931): 480. Jessup argued that unsound aggregate produced spalling.

[63] Henry D. Dewell, "Earthquake-Resistant Construction I - Data of Design," *Engineering News-Record* (26 Apr. 1928): 650-53.

plains, and advised against placing heavy cornices and towers on the tops of buildings. Giving buildings closed and symmetric shapes and using diagonal bracing was encouraged. Discussions about the preferred construction materials were common also. Steel was seen as being more reliable in terms of construction; however, a substantial frame was necessary to avoid failure. Reinforced buildings properly constructed were seen as effective as well, with the caveat that the buildings reached only a moderate height.[64]

It is difficult to produce evidence that any special design considerations regarding seismic issues were made in the design and construction of the Los Angeles River Bridges, beyond what was standard practice at the time. The HAER recording team, including both architects and historians, asked this question of the bridge retrofit engineers. No engineer could point to any specific original design decisions to demonstrate an extraordinary concern or innovative idea regarding structural seismic engineering. The possible exception is the Sixth Street Viaduct, constructed in 1932 and one of the last of the bridges in this recording project to be built. Its design suggests a conscious attempt to provide structural resistance to earthquakes. While its skewed design did not offer much in terms of symmetry, the light frames of the steel river arches replaced the reinforced concrete arches of earlier designs. The monumental piers in the middle of the bridge were of hollow construction, thus keeping the weight of the bridge down. Most significantly, "the structure was analyzed for horizontal forces equal to one-tenth the dead loads and applied at the centers of gravity of the various masses."[65] While not specified as created to allow for seismic forces, certain design criteria correlates with the general approach to seismic design in 1928.

Significance

The Los Angeles River bridges conveyed their significance most clearly when regarded as a set, a progression designed and constructed to serve the burgeoning transportation needs of the early twentieth century metropolis. The first set of these bridges, in 1910, established the general design theme of reinforced concrete, open spandrel, ribbed-arch design using the three-hinge arch. The later bridges were both variations on this theme and significant innovations experimenting with design and construction technology, and architectural fenestration. The bridges preceded much of the mid-century research into seismic design and so represented standard practice of the time in which they were built. The current generation of bridge engineers, responsible for the seismic upgrading of the last ten years, continued their predecessors' innovative traditions while at the same time accepting the responsibility of historic restoration and reconstruction of these great civic monuments to modern standards of seismic safety

[64] Dewell, "Earthquake-Resistant Construction," 701, 652. Much has been written concerning the relative value of structural steel and reinforced concrete as furnishing resistance, this being a controversial subject among builders. See Dewell, 701.

[65] Butler, "Sixth Street Viaduct," 387.

VI THE HISTORY OF THE SEISMIC RETROFIT OF THE LOS ANGELES RIVER BRIDGES

CHRONOLOGY

February 9, 1971	San Fernando Earthquake, (6.6 on the Richter scale) CalTrans begins retrofitting bridges with single-column supports.
October 1, 1987	Whittier Narrows Earthquake, (6.0 on the Richter scale)
October 17, 1989	Loma Prieta Earthquake, (7.1 on the Richter scale)
December 1989	Municipal Facilities Committee advises City Council to retrofit eighty-four City buildings and 459 City bridges.
February 27, 1990	City Council adopts a resolution to hold a special election for citizens to vote on a seismic bond issue.
June 5, 1990	The special election is held and voters approve Proposition G, a $376 million bond issue.
1990	Bridge Screening Process for seismic performance conducted by the Bureau of Engineering.
1992	City of Los Angeles secures $100 million in federal funding for the retrofit of City of Los Angeles owned bridges.
June 22, 1994	Programmatic Environmental Impact Report for the Seismic Retrofit of the Historic bridges over the Los Angeles River is certified by the City Council.

Earthquakes and the History of Seismic Retrofit in Los Angeles

Following every recent earthquake in California there has been public and political outcry for the seismic strengthening of public works, including bridges. The history of the Los Angeles River bridges seismic retrofit and restoration is tied to this reactionary cycle and is traceable back to at least the San Fernando Earthquake of February 9, 1971. Following the 1971 earthquake, the California Department of Transportation (CalTrans) made a careful analysis of the effect earthquakes had on highways, including bridges, in the effected areas. CalTrans used this information to identify earthquake-vulnerable highway structures throughout the state and to propose retrofit solutions. This cycle of seismic event, public debate, research, and retrofit has continued over the years after each major earthquake and has lead to significant advancement in the field of seismic design and an increase in the public safety of highway structures. CalTrans has been the lead agency in the State for addressing seismic issues on bridges for the last thirty years, and the City of Los Angeles and other local governments have historically followed the lead of CalTrans in seismic design.

The Los Angeles River bridges seismic retrofit and restoration project builds upon the work of CalTrans to extend seismic retrofit technologies to historic reinforced concrete bridges. While not subject to CalTrans plans because they are owned by the City of Los Angeles, the Los Angeles River bridges are nonetheless retrofitted with the seismic design principles developed by CalTrans. Unique to the seismic retrofit of the Los Angeles River bridges, however, is that the bridges' original architectural character has been restored. This combination of necessary seismic retrofit of older bridges with their historic restoration is a significant departure from days not long passed when a "tear it down and build a new one" ideology pervaded highway and bridge construction. The work of the City of Los Angeles' Bureau of Engineering represents a decision to recognize and appreciate the Los Angeles River Bridges and their historic role in the city. The seismic retrofit and restoration of the Los Angeles River bridges is an outstanding engineering achievement.

The seismic retrofit and restoration of the Los Angeles River bridges incorporated over three decades of seismic design research in California. This history of the seismic retrofit of bridges in California tells a story of a gradual learning process by engineers that has increased in fits and starts with each seismic event. CalTrans, following the studies of the 1971 earthquake, implemented a three phase statewide CalTrans plan. Phase one, carried out in the 1970s and 1980s, and completed by 1987, used steel cables at bridge piers and abutments to tie down elevated freeway decks.[66] These cables are visible on many bridges throughout the state. A number of the bridges in the Los Angeles River Bridges Recording Project were retrofitted in the 1980s using this technique.[67] Phase two of the plan, developed in the 1970s but approved in 1989 following the Loma Prieta earthquake, involved reinforcing single-column supports of bridges by wrapping them with flexible steel bars to prevent failure of the support in an earthquake. Phase three, an on-going project at the time of this recording project, applies phase two retrofit plans to bridges with multiple-column supports. This three-phase plan was primarily designed for freeway and highway bridges that are much younger than the Los Angeles River bridges.

The 1989 Loma Prieta earthquake in the San Francisco Bay Area, in which a section of the Nimitz Freeway in Oakland collapsed with great damage and loss of life, introduced new fervor into the seismic retrofit debate in cities statewide. Los Angeles

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[66] The objective of Phase one was to insure continuity at all of the bridge superstructure joints to prevent drop-type failures. Restraining cables and rods were used at expansion joints at the piers, and hinges and shear keys were used at abutments and bearings to hold the bridges together.

[67] These include the Fletcher Drive Bridge and the North Spring Street Viaduct.

was no exception and politicians quickly forced discussions on the seismic retrofitting of bridges within the City. Soon after the Loma Prieta earthquake an article appeared in the *Los Angeles Times* reporting that Assemblyman Richard Katz, a Sylmar Democrat who chaired the transportation committee, planned to take CalTrans to task for taking eighteen years to complete only phase one of the three-phase plan prepared after the San Fernando earthquake. He was upset that just two days after the Loma Prieta quake CalTrans announced that two Los Angeles County bridges were chosen as the initial targets of Phase two seismic retrofit. The bridges had been identified as vulnerable two years earlier, but CalTrans had not acted on the retrofit until pressured by the earthquake, Katz argued.[68]

Following the Loma Prieta event city officials took action. On October 25, 1989 the City Engineer of Los Angeles, Robert Horii, reported to the city council that many of the 416 bridges and viaducts maintained by the city required shoring.[69] Horii said "I don't believe the urgency was there until what recently happened last week (the Loma Prieta quake). We knew it could happen, but probably didn't understand the impact of it." Horii reported that as many as one-fourth of the city-maintained bridges and viaducts needed reinforcement. "The critical ones are the older bridges crossing the Los Angeles River. They are very old and they're very long." Los Angeles Mayor Tom Bradley directed Horii to conduct an inspection of all the bridges in the city, stating "While last week's earthquake is still fresh on everyone's mind, I believe it is a good time for us to reassess the safety of our own bridges."[70] The result of the mayor's directive to Horii was the December 1989 Municipal Facilities Committee report identifying 459 City bridges that were at risk. The bridges of the Los Angeles River Bridges Recording Project were included in this list.

The Bond Issue for the Seismic Retrofit of Los Angeles Bridges and Buildings

The source of funding, of course, had great influence on the form and scope of the bridge retrofits. Following the 1989 Loma Prieta earthquake the Los Angeles City Council instructed the City Administrative officer to report on the cost to seismically strengthen the City's public facilities and bridges. In December of 1989 the Municipal Facilities Committee reported to the City Council, advising that $376 million would be needed to repair the eighty-four municipal buildings and 459 bridges at risk. As a result of this report, on February 27, 1990, the City Council adopted Ordinance No. 165550 to hold a special election on Proposition G, a proposal that bonds to fund the retrofit would be paid through an increase in the property tax.[71]

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[68] Virginia Ellis and Frank Clifford, "2 L.A. Bridges to be Strengthened," *Los Angeles Times*, 21 Oct. 1989, page?

[69] The number of bridges needing seismic retrofit shifted frequently depending on who was generating the list. The Bureau of Engineering did a bridge screening process in 1990 and this became the official list.

[70] Jane Fritsch, "Council Gets Bad News on L.A. Bridges" *Los Angeles Times*, 25 Oct. 1989, page ?

[71] The ballot title, which consists of a short statement of the bond proposition, read, "SEISMICALLY DEFICIENT BRIDGES AND BUILDINGS GENERAL OBLIGATION BONDS, CITY OF LOS

Voters approved Proposition G at the June 5, 1990 election. The initial bond issue was for $37.7 million dollars, the amount that would be spent in the first phase of the retrofit. Following the approval of Proposition G, the task of overseeing the seismic retrofit was assigned to the Structural and Geotechnical Engineering Division of the Bureau of Engineering. This Bureau conducted a bridge screening process in 1990. Of the 459 City of Los Angeles-owned bridges identified in the Municipal Facilities Report, 118 were selected for retrofit, fifteen of which are the bridges of this recording project. The other bridges were dropped for a variety of reasons.[72]

The decision making process concerning the retrofit was tied to the cares and concerns of the politicians, citizens, and engineers of the City of Los Angeles, but was controlled most directly by the legal requirements attached to the sources of funding for the bridge retrofits. The retrofit of the bridges included in the Los Angeles River Bridges Recording Project was complicated by the fact that all the bridges were eligible for the National Register of Historic Places. Built between 1909 and 1934, their historical significance derives from their architecture and design, and their role in the development of the City of Los Angeles. As a result of their historical significance the bridges posed a difficult problem for the staff of the Bureau of Engineering because the engineers had to both protect public safety and abide by laws concerning structures of National Register importance. The city engineers considered three options: demolish the old bridges and build new bridges in their place; renovate the bridges while ignoring their historical significance; retrofit the bridges for seismic safety while maintaining and restoring their historic qualities. Both the first and second options failed to meet national Register Criteria. Additionally, option one was prohibitively expensive.

With the approval of Proposition G, Los Angeles could use city-generated bond money to retrofit the bridges. Other funding sources included the State Federal Gas Tax money, available through CalTrans. The Gas Tax money was a significant source of retrofit funding, yet the City of Los Angeles was not high on the priority list for the funding. This changed in 1992, partly due to Clark Robins appearing before the State Seismic Commission arguing to move Los Angeles higher on the priority list. Eventually the City received $100 million in Federal funds, freeing that amount of Proposition G money for other projects.

With the use of Federal funds, however, Federal preservation law mandated that each retrofit be evaluated according to the Secretary of the Interior's Standards for rehabilitating historic structures. This was not the case when the bridge retrofit was

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ANGELES PROPOSITION G: Shall the City of Los Angeles incur $376,000 indebtedness to reinforce, renovate and replace City-owned seismically deficient bridges and buildings?" Arguments for the proposition read:
"The San Francisco Bay Area experienced a big earthquake last October. A big earthquake could hit our area any time. Many of our bridges and public buildings could not withstand a powerful jolt. People could be killed or injured. This measure will allow the City to issue bonds to make 450 bridges and nearly 100 public buildings safe. This is the fairest way to pay for these repairs. Earthquake safety improvements are needed. This measure will save lives and make Los Angeles a safer place." No arguments against the proposition were submitted.

[72] 278 of the 459 bridges were dropped in the bridge screening process for the following reasons: the bridge in question already met code, the bridge in question had been recently retrofitted, and other reasons.

funded solely by the City of Los Angeles through Proposition G funds. Section 106 of the National Historic Preservation Act of 1966 requires that if a structure is listed or eligible for listing on the National Register of Historic Places, a Section 106 Report (a determination of whether the proposed projects will have an adverse effect) is mandatory to qualify for federal funds.[73] In the case of the Los Angeles River bridges, historic preservation consultants were hired to prepare these reports. The job of the consultant was to test each of the retrofit options proposed by either the city or city hired consultants against the Secretary of the Interior's Standards. If there was a finding that the retrofit caused an adverse effect to the historic bridge, then mitigation was necessary. On the Los Angeles River Bridges, one of the mitigatory measures was restoration of the bridges' original architectural features.[74] Restoration involved the replacement and repair of the historic fabric of the bridge structure, often including replacing or refurbishing the light standards, railings, columns, and other architectural details.[75]

Federal laws requiring mitigation of historic structures undergoing rehabilitation have enabled the historic preservation of the Los Angeles River bridges. While it may have been less costly to ignore the bridges' historic importance during the retrofit, this was not legally possible. The sources of funding dictated that the engineers had to be concerned with both seismic design and historic preservation. The resulting work has proven to be of national importance.

Earthquakes and How They Affect Bridges

Earthquakes are a shaking or trembling of the earth that is tectonic or volcanic in origin. In the Los Angeles area the earthquakes are tectonic, caused by deformations in the earth's crust. Earthquakes result in movement that is up-down, left-right, or forward-back, often in combination. The damage that earthquakes can cause to bridges falls into three categories: damage to the superstructure, damage to the substructure, and damage to the abutments. Damage to the superstructure can cause both a loss of girder support and rotation due to mass/rigidity offset (skew). Damage to the substructure involves column

[73] Implementation of the 106 process is defined in 36 Code of Federal Regulations part 800, Protection of Historic Property, Subpart B. Prior to the City of Los Angeles receiving federal funding for the bridge retrofit City engineers, including Clark Robins, held meetings with the City of Los Angeles Cultural Heritage Commission to discuss retrofit plans for the bridges.

[74] Historically it has been very difficult to appropriate money for the restoration of the architectural features of bridges. Money has only been available for the improvement or replacement of a bridge. This fact makes the restoration of the Los Angeles River Bridges a particularly interesting case. According to Clark Robins, in the early 1970s the 6th Street Viaduct was one of the first bridges in the United States to receive money for the repair and rehabilitation of the existing structure. The money was secured by changing the wording of the plans from "Repair of the 6th Street Viaduct" to "Improvements for the 6th Street Viaduct." By using the word "improvements" the bridge became eligible for gas tax money. This story illustrates the policy of expansion and improvement in the mindset of transportation policy makers and planners in the past, though this may be changing with cases such as the Los Angeles River Bridges.

[75] See HAER, No. CA-286, "Franklin Avenue Bridge," forthcoming, for a detailed case-study discussion of the mitigation process.

moment failure, column shear failure, or footing failure. Damage at the abutments includes abutment movement/failure and approach settlement.[76]

Buildings and bridges, indeed any structure, is affected by earthquakes. The measure of a structure's performance in an earthquake is its ductility, how well it flexes to absorb and release energy. In reinforced concrete structures it is the reinforcement that confines the concrete and determines its performance in an earthquake. Reinforcing bar must yield and release energy without breaking and failing, making it a prime design criteria for engineers. If the reinforcement is widely spaced in a column, the column may break at one point during an earthquake. If the reinforcement is more closely spaced then the column is more likely to bend, creating many small breaks as opposed to one catastrophic break.

The Common Seismic Deficiencies of Bridges and their Solutions

Retrofitting bridges for enhanced seismic performance is an art, not an exact science. Designers of new bridges can often follow codes that allow for adequate seismic performance without requiring detailed conceptual considerations of how the bridge works. Retrofit designers, however, face unique bridges requiring unique seismic retrofit solutions.[77]

The retrofit designer must create strategies based on theoretical and conceptual ideas about the performance of individual bridges. The retrofit design of a bridge is a three-step process, involving analysis of its seismic performance, proposal of design solutions for increasing that performance, and the testing of these solutions by computer model and often by laboratory testing of isolated design elements.

Five common deficiencies were found in the bridges in the Seismic Bond Bridge Program. All five of these deficiencies were found in the bridges of this Recording Project. The first was a loss of support at the rocker bearings and expansion hinges, generally where the deck rests on the bridge supports. During earthquakes, the steel rocker bearings and roller bearings, which are necessary to allow the bridge to expand and contract, have proved to be the most vulnerable of all bridge components. In major earthquakes the bridge deck shakes off its supports, resulting in collapse of the superstructure. This occurred in 1971, 1987, and 1989. The retrofit strategy limits the relative displacement at joints and thus decreases the chance of the loss of support. This is done in a number of ways, depending on the particular situation of the bridge in

[76] The following are milestones in the seismic design of bridges as outlined in Seismic Design of Highway Bridges-Training Course, Federal Highway Administration, Imbsen & Assoc., Inc. 1989: 1956-AASHTO Static Load Approach; 1968-CALTRANS Dynamic Characteristics introduced; 1971-San Fernando Earthquake bridge damage; 1973-CALTRANS new criteria, seismicity, soil effects, dynamic characteristics, ductility reductions; 1975-AASHTO adopted CALTRANS criteria; 1978 ATC-6 Study funded by FHWA; 1983 ATC-6 Study adopted by AASHTO as "Guide Spec." Additional milestones include detailed study of bridge performance and failure following the 1987 Whittier earthquake, and the 1989 Loma Prieta earthquake.

[77] In the last thirty years great advances have been made in the mathematics of seismic retrofit, and research is continuing. Please refer to the source list for this chapter for more information on seismic retrofit technology and planning.

question: by placing longitudinal cable restrainers at the joint; by extending the bearing seat; or by replacing the rocker bearing (which is subject to failure) with elastomeric bearing pads and other sophisticated energy-dissipating devices. When transverse-bearing movement results in instability of the structure, either concrete shear keys or caissons added on each side of the abutments can resist the transverse loads.

The second deficiency is column failure, where there is the sudden loss of flexural or shear strength in the column, resulting in structural collapse. The loss of flexural strength in a column can result from an anchorage failure in the main reinforcing steel at the column footing or bent cap, a failure of splices in the main reinforcement, or the loss of transverse confinement followed by the crushing of the concrete and buckling of the main reinforcing steel in the column.[78] Shear failure in a concrete column can occur suddenly and can result in the rapid disintegration of the column. The best solution to column failure is to protect the columns against having earthquake forces transferred to them by the rest of the bridge structure. A force-limiting device that uses the principles of seismic isolation alters the dynamic response of the bridge and reduces the structure force on the columns. Another method is to improve confinement of the column by the addition of transverse reinforcement, which increases the ability of the column to withstand repeated cycles of loading beyond the elastic limit of the column and prevents failure. Constructing an infill concrete shear wall between individual columns in the bent can increase the transverse resistance of multi-column bents. Depending on the shape of the column, cylindrical or elliptical steel jackets can be used to provide confinement and enhance the shear strength of the column. Rectangular steel jackets with stiffened angles and bolted connections can be tightened to provide increased shear capacity and confinement.

The third common deficiency is the failure of pier walls due to inadequate reinforcement. An anchorage failure, a failure of reinforcement splices, or the loss of transverse confinement can cause the loss of flexural strength during an earthquake. The solution to pier wall failure is to add reinforcing to the existing pier wall using a layer of reinforced concrete with extensive doweling to connect the additional layer to the existing pier wall.

Foundation failure is another common deficiency in bridges in the Seismic Bond Bridge Program. The failure of the column footing is often due to the absence of a top layer of reinforcement. During an earthquake this can result in flexural cracking of the footing concrete and the loss of anchorage for the columns' longitudinal reinforcement. The solution to this is a concrete cap of constant thickness that is cast directly on top of the footing. Steel dowels, bonded into drilled holes, connect the new cap with the existing footing. A top layer of conventional reinforcement provides negative moment capacity.

The last of the common deficiencies is abutment failure. During an earthquake the lateral movement of an earth-retaining abutment or a consolidation of the abutment fill may cause a loss of accessibility to the bridge during an earthquake. Longitudinal movement, if not restrained, could shear off the back wall. To minimize this displacement the most common solution is to stiffen the abutments by adding a seismic anchor slab

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[78] A bent cap connects the tops of columns that are in a row (a bent). Often the bridge deck then rests on the bent cap.

with concrete piles. An alternative is to provide tension anchors with concrete "deadmen," concrete masses used as anchoring points. If stiffening the abutments is not possible, then the solution is to provide approach slabs with positive ties to the abutments to prevent them from pulling away.

The Character of the Seismic Retrofit and Architectural Restoration of the Los Angeles River Bridges

The seismic retrofit of the Los Angeles River Bridges involved the careful combination of the restoration of the historic bridge fabric with the insertion of modern seismic technology. For the engineers of the City of Los Angeles Bureau of Engineering this was not a typical design problem, and involved the new step of having a historic preservation consultant verify if they were satisfying Federal mitigation requirements for the retrofit funding. The prime responsibility was always public safety, but the engineers, together with the historic preservation consultants, proved very inventive in applying their retrofit technology to the bridges. Each of the bridges proved to be a unique situation that required an individual solution.

The Process of the Physical Retrofit

The process of retrofitting a bridge, from analysis of the bridge to completion of construction, is a multi-year effort. In the case of the Los Angeles River Bridges the Bureau of Engineering of the Department of Public Works oversees the complete process. The retrofit process begins with a city engineer creating a computer model of the existing bridge based on the as-built drawings in the Bureau of Engineering records.[79] With this computer model the engineer can identify deficiencies within the bridge structure. The demand-capacity ratio (DC ratio) is a number often used by the retrofit engineers to evaluate the probable performance of individual structural members of the bridge in a seismic event, based on the demand load of the event versus the capacity of the member to withstand the load. The engineer will then analyze a number of possible retrofits of these individual members, based on both the engineer's expertise and experiments. At this time the engineer constructs a model of the overall performance of the bridge based on various combinations of the proposed retrofits for the individual members. The engineer can then construct the best possible retrofit solution. But to determine the best possible solution there are a number of variables besides performance that are considered, including aesthetics, cost and historical integrity. For instance, shear walls are excellent at controlling deflection in bridges. But in open-spandrel arch bridges, like many of the Los Angeles River bridges, shear walls in the longitudinal direction would ruin the visual appeal of the arches. Therefore, other solutions are sought, such as column replacements, anchor piles in the abutments, beefing up the arch ribs, and column jacketing. The final result of the retrofit design engineers' work is a carefully considered

[79] Computer models are created using software such as SAP 2000, and SEI SAP. The University of California, San Diego, and the University of California, Berkeley, are leading research centers on seismic design and performance.

balance of the performance, cost, and aesthetic concerns, while meeting the Federal requirement of Section 106.

Much of the work of the design and analysis of the Los Angeles River bridges was handled by the engineers of the Bureau of Engineering. However, due to political and economic pressures, the bridge retrofit program was sped up in the early 1990s.[80] In order to meet this demand the Bureau of Engineering hired private-sector consultants to aid in the analysis and design of the bridge retrofits. Consultants were hired to conduct analysis of the bridges, to provide possible retrofit solutions, and to prepare plans, specifications, and estimates (P.S.&E's.). The consultants performed tasks parallel to the work of the city engineers. Consultants were also hired to perform independent checks on the work of the city engineers, while the city engineers performed the same checks on the work of the consultants. Once construction started on a bridge retrofit, however, the city engineers handled all of the work.

After a retrofit design strategy was decided upon, the PS&E's were prepared. This set of documents goes through review for the approval of the design engineer, delineator, plan checker, project manager, division engineer, deputy city engineer, and finally the city engineer. Once materials are signed, they are used to request permits to perform the work.[81] Following approval of the permits the bridge retrofit construction job is advertised.

An estimate of the cost of the retrofit construction is prepared by the City of Los Angeles. It is expected that the bids of the contractors come to within fifteen percent of the City estimate, and the City is obligated to accept the low bid for the project. The selected contractor must provide a performance bond, a bid bond, and a material bond before a contract is signed. Once a contract is signed there is a pre-construction meeting where the city engineers and the contractors define the roles of each person involved in the project and agree upon a schedule and other key issues. The City's design engineer often becomes the construction manager in all dealings with the contractor. The actual construction often takes one and one-half to two years for the river bridges. During this time there are many issues that need to be addressed, including traffic control and community outreach. From October to April there are restrictions on entering the river channel. Weekly meetings cover construction issues as well as other issues. Contractors are paid monthly on a "cost-loaded" schedule according to their cost as outlined in the schedule. Ten percent of the contractor's fee is held in retention until final project approval is obtained.

All of the bridge retrofit construction projects have a full-time City inspector. At the end of the project a "final inspector," also from the City, reviews the entire construction project and must give approval before the contractor is paid in full. The final inspector prepares a "punch list" of items yet to be done that the contractor must satisfy. The Office of Contract Compliance must give approval that the contractor met the obligation under Federal Law of hiring Disadvantaged Business Enterprises (DBE) to

[80] The recession of the early 1990s prompted a speed-up of the retrofit program in order to take advantage of supposed cost savings in construction to the City.

[81] Permits that may be needed include rights of entry for the river channel and railroad right-of-ways.

participate in the project, and that the contractor paid the wages as specified. The Board of Public Works must approve the final project.

The Retrofitted Bridges and the City of Los Angeles

As the seismic retrofit and restoration of each of the historic Los Angeles River bridges is completed, the reopening becomes a cause for public celebration. Often there is a bridge opening ceremony such as those held for the Olympic Boulevard Bridge and the North Broadway Viaduct.[82] These ceremonies bring together the public officials, community groups, and engineers, consultants, and construction workers in a celebration of the continuing importance of the bridges as connectors within the City, and in the quality of their workmanship and the link they provide for the residents of Los Angeles between their past and their future.

[82] See Douglas P. Shuit, "Historic Bridge to Downtown Reopens," *Los Angeles Times*, 31 Mar. 2000, page?

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